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Development and analysis of lithologically controlled regional curves of hydraulic geometry for Appalachian mountain streams, Ridge and Valley Physiographic Province, Pennsylvania

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Development and Analysis of Lithologically Controlled Regional Curves of Hydraulic Geometry for Appalachian Mountain Streams, Ridge and Valley Physiographic Province, Pennsylvania

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Abstract

Development and Analysis of Lithologically Controlled Regional Curves of Hydraulic Geometry for Appalachian Mountain Streams, Ridge and Valley Physiographic Province, Pennsylvania

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Regional curves of hydraulic geometry are frequently constructed for physiographic provinces, regions that have similar geologic structure, climate, and geomorphic history. As a result, the factors controlling channel form are more alike than would be the case for streams across widespread geographic regions. However, geology can vary significantly within a physiographic province. The purpose of this study, therefore, was to determine if regional curves would be more precise predictors of hydraulic geometry if developed for geologically similar streams within a physiographic province. A total of 34 reaches on six ungauged mountain streams in the Ridge and Valley Physiographic Province of Pennsylvania were used to develop lithologically controlled regional curves for drainage area versus bankfull cross-sectional area, bankfull width, and bankfull mean depth.

The slope, y-intercept, and R^2 value of the non-carbonate lithologically controlled regional curves were compared to three distinct regional curves of varying watershed size and physiography. These comparisons reveal that lithologically controlled regional curves for bankfull cross-sectional area are consistently statistically different than the other three curves. The factors that may influence differences in the regional curves include bedrock geology, geologic structure, physiography, channel gradient, watershed size, riparian vegetation, and land use. Comparison of R^2 values shows regional curves derived from a larger sample size and including a majority of larger watersheds (> 75 km^2) produce less variance. An additional regional curve was derived by combing hydraulic geometry data from the lithologically controlled watersheds and non-carbonate watersheds initially investigated by Chaplin (2005). Higher R^2 values indicate the combined curves developed with a larger sample size and dominated by larger watersheds produce less variance compared to the lithologically controlled curves. Future regional curve investigators should include ungauged watersheds, increase sample size, and more fully constrain the variables controlling natural channel dimensions to assess if more precise hydraulic geometry relationships can be developed within physiographic provinces.

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I am additionally indebted to Jeffrey Chaplin and Robert Jarrett of the United States Geological Survey for their technical assistance and comments related to data analysis and the subsequent research conclusions. I am also indebted to the Geological Society of America, for providing financial support in the way of a graduate student research grant, which helped offset the cost of field data collection.

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I would lastly like to express my gratitude for the love and support provided by my family. I am indebted to my brother, David, for his friendship and encouragement. Most importantly, I extend my deepest gratitude to my parents, for their unending support, instilling in me their work ethic, and belief that education is the key to success in life.

I dedicate this thesis to my father, Dewaine, who provoked my interest in the outdoors and streams at a young age, through yearly camping trips along Laurel Run, in the Ridge and Valley Physiographic Province of Perry County, Pennsylvania.

Table of Contents

List of Figures

List of Tables

Introduction

Continual expansion of the human population and commercial and residential development of the natural world has led to impairment and modification of many stream channels (Swift 1984). Several anthropogenic activities result in the degradation of stream channels, including channelization for drainage and agricultural purposes, urbanization, mining, and flow regulation through dam placement (Wohl 2000). These anthropogenic activities may result in changes in the water and sediment discharge or direct changes to the morphology and geometry of channels (Wohl 2000). Direct modifications of stream channels or changes in the hydrologic or sedimentologic regime often result in instability. As anthropogenically induced instability ensues, excessive aggradation or degradation often becomes apparent, disrupting the equilibrium condition to which natural channels tend (Leopold 1994).

Stream restoration, or natural channel design, is a relatively new field that has been a useful tool to remediate impaired streams (Skidmore et al. 2001). A common natural channel design approach involves using empirical data to develop regional curves to predict the dimensions of stable design reaches (Wharton et al, 1989). A regional curve is "an ordinary least-squares regression expressed as a power function that relates drainage area to selected bankfull response variables" (Chaplin 2005). The most common bankfull response variables for which regional curves are developed include discharge, cross-sectional area, width, and depth. Accordingly, bankfull response variables can be estimated from regional curves, if the drainage area for a specified location is known. The development of such relations often involves large data sets and the derived equations display average flow or channel conditions (Skidmore et al. 2001).

Regional curves are frequently constructed for physiographic provinces, or regions that have similar geologic structure, climate, and geomorphic history (Dunne and Leopold 1978). As a result of this physiographic restriction, the factors controlling channel form are more alike than would be the case for streams across more widespread geographic regions. However, geology can vary significantly within a given physiographic province (Sevon 2000) and this variation may be a major cause of outliers that deviate from regional curves. Regional curves have also been historically created only from stations with U.S. Geological Survey stream-flow gauges (Chaplin 2005) (Keaton et al 2005) (Dunne and Leopold 1978). However, solely relying on watersheds with stream-flow gauges limits the ability of the derived regional curve to accurately portray the spectrum of hydraulic geometry conditions within a physiographic province. The majority of stream-flow gauges have been placed on lowland rivers with drainage areas larger than most small low-order mountain streams. Therefore, it was the goal of this study to investigate whether regional curves of hydraulic geometry within the Ridge and Valley Physiographic Province of Pennsylvania should be developed for lithologically similar, ungauged mountain streams. A working hypothesis for this project was that mountain stream channels containing abundant, cobble to boulder sized alluvium will be wider and shallower than predicted by regional curves developed for whole physiographic provinces.

Importance of Bankfull Discharge

The bankfull discharge is considered the most important flow event in controlling and maintaining channel form. Wolman and Miller (1960) advanced this idea in their investigation of the frequency and magnitude of flow events in relation to channel maintenance and sediment transport. Wolman and Miller (1960) recognized that channel form is influenced by a natural range of flow conditions. They noted that the channel and floodplain of any stream are principally constructed by the processes of lateral accretion, or point bar development (Wolman and Miller 1960). Through analysis of the transport of suspended sediment by frequent and infrequent flows, Wolman and Miller (1960) found that the overwhelming majority of total sediment removal from watersheds resulted from moderate-magnitude, moderate-frequency flows. They suggested that although catastrophic flow events have the ability to transport large quantities of sediment, they occur so infrequently that their overall importance is minimal. In humid regions, the bankfull discharge has a recurrence interval of one to two years (Wolman and Miller 1960). The bankfull discharge is commonly referred to as the effective or dominant discharge, due to its importance in controlling and maintaining channel form (Knighton 1998).

Williams (1978) investigated the recurrence interval of the bankfull discharge using recurrence frequency data from several rivers in the United States. Recurrence data were derived from annual maximum series of instantaneous discharges occurring at the elevation of the active floodplain. A frequency distribution of the bankfull discharge was constructed and yielded a mean recurrence of approximately 1.5 years, although a broad range of recurrence intervals exists, spanning from 1.01 to 32 years (Williams 1978). Only approximately a third of sampled rivers have a bankfull discharge recurrence interval near 1.5 years, so Williams (1978) concluded that the mean recurrence of 1.5 years for bankfull discharge was not reliable. Variance in the recurrence interval of the bankfull discharge was attributed to channel gradient (Williams 1978); analysis showed as channel gradient increased, the recurrence interval of bankfull discharge also increased (Williams 1978).

Controls on Hydraulic Geometry

The hydraulic geometry of any natural river channel is adjusted to accommodate the discharge and sediment load supplied to it (Leopold 1994). The independent variables that indirectly control hydraulic geometry include geology, climate, soils, vegetation, and basin physiography (Knighton 1998). In unglaciated terrains, channel sedimentology is controlled by the bedrock geology that underlies the drainage basin (Knighton 1998). The composition of the channel bed and banks is primarily influenced by channel sedimentology and riparian vegetation (Knighton 1998). Over time, stream channels adjust to their current climatic regime and a state of stability or equilibrium is commonly achieved. Equilibrium is attained when the magnitude of erosive forces caused by flow and the magnitude of the resisting forces of the bed and banks are equal, and neither aggradation nor degradation of the channel occurs.

The composition of bed and bank materials exerts an influence on the strength of the channel boundary, and as a result influences channel form. The strength of the channel banks is largely dependent on the cohesiveness of sediments, which is influenced by basin geology. In his investigation of alluvial channels with minimal bedload in the Great Plains, Schumm (1960) compared channel dimensions to the percentage of silt and clay (M) in the channel banks for several rivers. He concluded that channel banks with a high percentage of silt and clay produce deep and narrow channels (Schumm 1960).

In an effort to distinguish between the primary means of sediment transport, Schumm (1963) subdivided natural channels into three categories, using the percentage silt and clay (*M*) in the channel and the percent of bedload out of the total load. Arbitrary threshold percentages were used to distinguish three channel types: bedload, mixed load, and suspended load (Schumm 1963). Schumm characterized stable bedload channels as having width-depth ratios greater than 25 and relatively steep gradients (Schumm 1963). Stable mixed load channels were characterized as having width-depth ratios greater than 7 and less than 25 and moderate gradients (Schumm 1963). Stable suspended load channels have gentle gradients and a width-depth ratio less than 7 (Schumm 1963).

Subsequently, Osterkamp (1980) distinguished the influence of discharge and channel sedimentology on channel form whilst investigating several alluvial reaches in Kansas. Channel geometry and sedimentology data were collected for several rivers of varying hydrologic regimes. Osterkamp (1980) found that rivers transporting mostly silt and clay in suspension produced the deepest and narrowest cross-sections. More importantly, discharge was identified as the primary control on channel size, whilst sediment load was more influential in controlling channel shape (Osterkamp 1980).

In an effort to further understand how drainage basin geology influences channel sedimentology and channel form, Hack (1957) studied channel sediments along the longitudinal profile of several bedrock influenced alluvial streams in Virginia and Maryland. Hack (1957) noted that as channel slope increased, the size of bedload sediments also increased. Several explanations were postulated to account for the change in size of bed load sediments, including mechanical weathering, or breakage of sediments by abrasion (Hack 1957). Resistant lithologic units, such as quartzite or sandstone, persist downstream for longer distances due to their inherent resilience against abrasion. Weaker lithologic units, such as shale and carbonate bedrock, are more susceptible to breakage and disintegration, and accordingly do not persist for great distances downstream from source areas.

Hack (1957) also compared the dimension of the channel cross section to varying lithologic units. He concluded that non-resistant lithologies produced deeper cross sections than those underlain by more resistant lithologies (Hack 1957). In a similar study of several streams in central Pennsylvania, analogous conclusions were drawn with respect to the resistance of underlying strata and the dimension of the channel cross section (Brush 1961).

Hack (1965) later compared channel slope to stream length for several streams located in different lithologies in the Shenandoah Valley in Virginia and West Virginia. Channel slopes were, on average, seven times greater in sandstone watersheds than in shale watersheds (Hack 1965). Streams located in carbonate rocks displayed an intermediate character, having slopes between those of sandstone and shale areas. High variance in channel slope within carbonate watersheds was attributed to some carbonate units containing significant amounts of resistant chert, which may persist in the channel and produce steep slopes (Hack 1965).

Miller (1991) investigated channel sediments and dimensions along bedrock-influenced alluvial streams in Indiana. The study streams were categorized on the basis of the dominant underlying lithology, either as siliciclastic or carbonate strata. Siliciclastic channels were characterized by short bedrock reaches and extensive (> 250 m in length) alluvial reaches, dominated by sandstone alluvium (Miller 1991). The carbonate channels exhibited extensive bedrock reaches (> several hundred m in length), interspersed with short alluvial reaches dominated by thin sandstone alluvium with fewer carbonate clasts (Miller 1991). The pervasiveness of extensive carbonate bedrock reaches was attributed to greater storage capacity for alluvium in floodplains and long distances from the siliciclastic source area. Miller concluded that siliciclastic channel geometries appear to be sized to convey bedload of a particular size, whereas carbonate channel cross sections are adjusted to the composition of the underlying strata, not the supplied bedload.

<u>Previous Regional Curve Investigations</u>

The quantitative understanding of natural channels was advanced by Leopold and Maddock (1953) in their fundamental study relating discharge to a number of dependent variables, including velocity, channel width, and channel depth. Hydraulic geometry data from several streams in the central and western United States were used to assess how velocity, width and depth vary through a range of flow conditions. The independent variable of discharge was plotted versus each of the dependent variables. A power-function trend line was added to each of the regression plots, using ordinary least-squares regression, producing an equation containing a constant of proportionality relating discharge to the other variables and an exponent relating how discharge impacts each dependent variable. Leopold and Maddock (1953) showed that all of the dependent variables increase with the increased discharge, but velocity increases only slightly, depth increases moderately, and width increases rapidly (Leopold 1994).

The concept of regional curve equations relating drainage area to a bankfull channel variable was introduced by Dunne and Leopold (1978), while investigating the channel geometry of the Upper Green River Basin, Wyoming. Initially, the importance of the bankfull stage was realized because of its significance to flooding and environmental management, but identification of bankfull stage proved to be problematic where a narrow and poorly defined floodplain was present. Therefore, Dunne and Leopold (1978) collected hydraulic and channel geometry data for the bankfull stage at several reaches in the Upper Green River Basin and used univariate regression to derive equations displaying how average conditions varied with drainage area. As a result, the equations relating hydraulic geometry to a bankfull response variable could then be used to aid identification of bankfull stage in reaches where the floodplain is poorly defined. Similar drainage area vs. bankfull channel geometry data were later assembled for basins in the San Francisco Bay area and Southeastern Pennsylvania (Dunne and Leopold 1978), and the Upper Salmon River, Idaho (Emmett 1975). Combined plots of regional curves of hydraulic geometry show obvious geographic trends in the relationship between drainage area and each bankfull channel variables. Dunne and Leopold (1978) concluded that climate, along with physiography and geology, were the causes of variability in the relationships. Accordingly, the term 'regional curve' was applied to the developed equations because of their significance to areas of similar climate, geology, and geomorphic history.

Chaplin (2005) developed regional curves for non-urban, small watersheds in Pennsylvania and selected adjacent areas in Maryland. Chaplin's study area included seven physiographic provinces; Piedmont, Ridge and Valley, Appalachian Plateaus, New England, Blue Ridge, Coastal Plain, and Central Lowland. Data were collected from 66 flow gauging stations and adjacent reaches; ordinary least-squares regression techniques were used to develop curves relating drainage area to bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth (Chaplin 2005). Statistical methods were employed to determine what factors, including physiography, percent carbonate bedrock, and percent of watershed that was glaciated, influenced the resultant regional curves (Chaplin 2005). Only percent carbonate bedrock statistically influenced the slope of the equations of the regression lines, thus the development of regional curve equations for non-carbonate (≤ 30% carbonate) bedrock watersheds (Table 1) and carbonate (> 30% carbonate) bedrock watersheds was carried out (Chaplin 2005). Attributes of the non-carbonate regional curves, including the slope and y-intercept, coefficient of determination, and f-statistic values are presented in Table 2.

Objectives

The objectives of this study are as follows:

1. To develop regional curve equations for bankfull channel width, bankfull mean depth, and bankfull cross-sectional area for lithologically controlled mountain watersheds in the Ridge and Valley Physiographic Province, Pennsylvania. In this study, the phrase lithologically controlled refers to watersheds that have a high degree of homogeneity in lithology.
2. To compare the slope and y-intercept of the lithologically controlled regional curve equations to published regional curves, in an effort to determine if lithologically separate curves should be created within physiographic provinces, and to compare R^2 values from lithologically diverse and lithologically similar regional curves to determine if a decrease in variance is achieved.
3. To conduct "pebble-counts" on each measured reach to quantify the relationship between bedload texture and drainage area.

USGS Gage I.D.	Physiographic Province	Drainage Area (km^2)	Bankfull XSA (m^2)	Bankfull W (m)	Bankfull MD (m)	Percent Urban	Percent Forested
1449360	v	129.24	22.11	25.15	0.84	4.7	68
1450500	v	198.65	36.33	44.50	0.83	1.2	70
1451800	v	137.27	30.84	32.31	0.95	1.1	33
1452000	v	196.32	28.89	32.31	0.82	3.7	34
1468500	v	344.47	53.51	34.44	1.55	---	---
1469500	v	111.11	13.47	16.92	0.79	2.4	77
1470756	v	411.81	62.34	47.85	1.30	1.3	40
1516500	a	31.60	14.12	21.70	0.76	0.1	47
1518420	a	192.44	44.50	33.22	1.33	0.1	55
1533250	a	30.56	7.46	17.80	0.32	0.2	63
1537000	v	83.92	10.68	14.97	0.71	---	---
1538000	v	113.44	17.65	21.12	0.84	5.8	83
1542720	a	21.60	4.31	8.56	0.52	0	65
1542810	a	13.57	3.98	13.53	0.41	0	99
1543700	a	471.38	69.77	54.56	1.26	0.1	93
1544500	a	352.24	50.54	48.46	1.05	0	96
1545600	a	119.66	19.79	25.82	0.79	0	100
1547700	v	114.22	14.86	19.45	0.78	0.2	78
1549500	a	97.64	28.06	28.10	1.00	0.1	78
1550000	a	448.07	72.19	61.57	1.17	0.1	80
1552500	a	61.64	20.44	20.88	0.98	0	92
1553700	v	132.87	28.06	22.71	1.22	0.5	31
1555500	v	419.58	63.27	40.54	1.56	1	67
1565000	v	424.76	50.07	35.36	1.45	1.2	63
1566000	v	554.26	113.34	60.96	1.87	0.1	70
1567500	v	38.85	10.03	13.17	0.77	0.1	49
1568000	v	536.13	87.33	61.57	1.12	0.9	68
1569340	v	13.70	6.55	12.62	0.53	1.9	34
1613050	v	27.71	6.22	11.09	0.57	0	70
3011800	a	120.18	16.44	19.05	0.86	1	96
3021410	a	135.46	28.99	19.32	1.53	0.8	57
3022540	a	80.29	16.72	22.34	0.76	0.2	64
3026500	a	20.31	7.51	10.91	0.70	0.1	94
3028000	a	163.17	29.26	29.63	0.90	0.6	91
3034500	a	226.36	47.66	30.48	1.55	0.3	73
3039925	a	8.94	3.14	8.32	0.38	0.1	99
3049000	a	354.83	49.98	34.14	1.46	0.5	50
3049800	a	14.97	3.03	5.49	0.55	0	80

Table 1. Characteristics of sites used to develop Chaplin's (2005) regional curves for non-carbonate watersheds. Key to symbols in table: [XSA] Cross-Sectional Area, [W] Width, [MD] Mean Depth, [v] Ridge and Valley, [a] Appalachian Plateaus, [cl] Central Lowland, [p] Piedmont, [---] missing data.

USGS Gage I.D.	Physiographic Province	Drainage Area (km^2)	Bankfull Cross-Sectional Area (m^2)	Bankfull Width (m)	Bankfull Mean Depth (m)	Percent Urban	Percent Forested
3072880	a	45.32	16.17	17.53	0.93	1.4	63
3080000	a	313.39	56.30	49.07	1.15	0.9	68
3102500	a	269.36	38.00	22.10	1.72	0.2	30
4213075	cl	11.53	2.24	8.87	0.26	---	---
1471980	p	221.44	43.48	27.46	1.58	1.5	56
1472157	p	153.07	29.36	26.55	1.11	1	64
1472198	p	98.42	28.24	35.66	0.81	2	54
1472199	p	59.57	18.77	29.41	0.64	1.9	61
1475850	p	40.92	14.96	17.53	0.85	15	61
1477000	p	158.25	28.15	21.21	1.33	19	55
1480300	p	48.43	11.89	17.50	0.68	1.5	31
1480500	p	118.62	16.63	23.65	0.71	2.2	42
1480617	p	142.45	24.90	29.57	0.84	2.2	42
1578200	p	22.53	5.92	8.90	0.68	0.9	20
1586210	p	36.26	9.85	13.53	0.73	---	---
1586610	p	72.52	17.56	20.79	0.84	---	---
1639500	p	264.18	57.23	30.78	1.87	---	---

Table 1. Characteristics of sites used to develop Chaplin's (2005) regional curves for non-carbonate watersheds - continued. Key to symbols in table: [XSA] Cross-Sectional Area, [W] Width, [MD] Mean Depth, [v] Ridge and Valley, [a] Appalachian Plateaus, [cl] Central Lowland, [p] Piedmont, [---] missing data.

Response Variable	Equation	Slope	Y Intercept	R^2	F-statistic
Cross-Sectional Area	$CSA=0.524DA^{0.797}$	0.797	0.524	0.923	232.73
Width	$W=2.916DA^{0.449}$	0.449	2.916	0.813	110.29
Mean Depth	$D=0.195DA^{0.330}$	0.330	0.195	0.718	88.13

Table 2. Summary of quantitative attributes for Chaplin's (2005) regional curves for non-carbonate watersheds.

Study Area

Location

The study area is located in the Ridge and Valley Physiographic Province, South-Central Pennsylvania (Figure 1). The Ridge and Valley is bound to the east by the Blue Ridge Physiographic Province and to the west by the Appalachian Plateaus Physiographic Province (Fenneman 1928). Laurel Run, Horse Valley Run, Sherman Creek, South Branch Little Aughwick Creek, Conodoguinet Creek, and West Licking Creek watersheds were investigated in Fulton, Franklin, Cumberland, Perry, Juniata, Mifflin, and Huntingdon counties, Pennsylvania (Figure 2). All watersheds are characterized by a trellis to dendritic drainage pattern, an elongate shape, relatively small drainage areas (< 75 km^2), and divides underlain by resistant quartz sandstone of either the lower Silurian Tuscarora Formation or the upper Ordovician Bald Eagle Formation. The morphology of all study streams is characterized by well-developed sequences of pools and riffles. Portions of all of the study streams are located in state game lands or state forests.

Structure

The Ridge and Valley Physiographic Province consists of a generally parallel sequence of northeast to southwest trending ridges and valleys (Thornbury 1965). Topography is intimately linked to bedrock geology; ridges are capped by resistant strata and valleys underlain by weaker strata (Fenneman 1928). The western section of the greater province includes two sub-provinces, the Appalachian Mountain Section and the Susquehanna Lowland Section (Sevon 2000), both partially included in the study area.

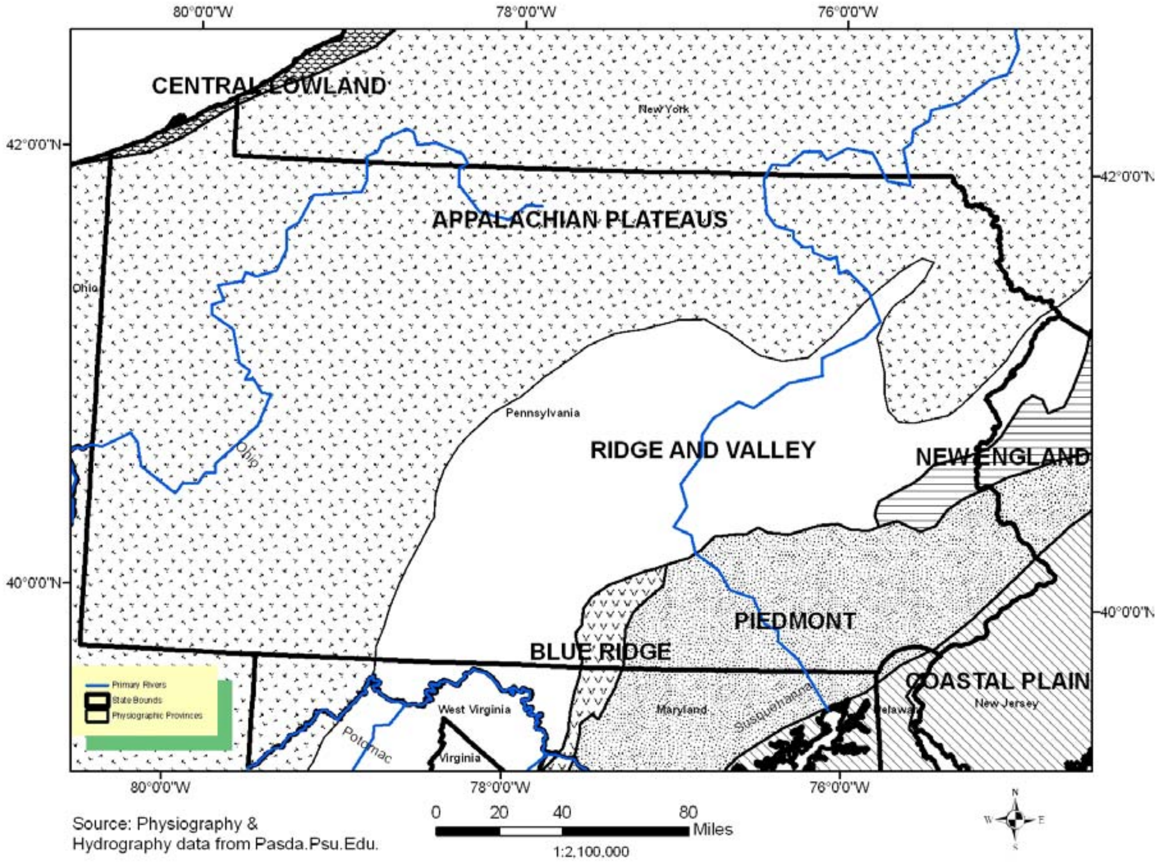

Figure 1. Physiography and major rivers of Pennsylvania and adjacent areas.

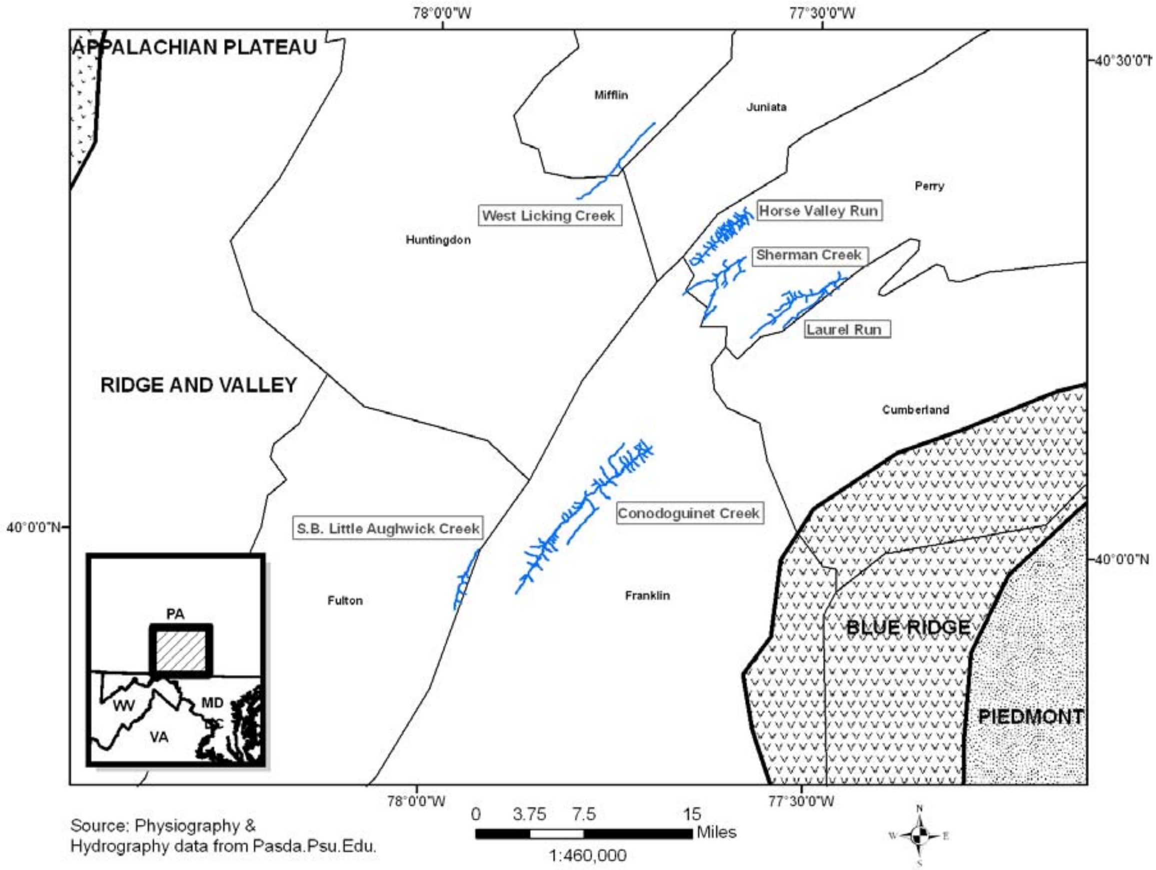

Figure 2. Study area map showing physiographic provinces, counties, and hydrography.

The structure of the Appalachian Mountain and Susquehanna Lowland Sections consists of "open and closed plunging folds having narrow hinges and planar limbs", with minor faulting (Seven 2000). The origin of the present-day landscape is attributed to fluvial erosion, and to a lesser extent, periglacial mass wasting and solution of carbonate rocks (Sevon 2000).

Geology

The bedrock geology in the study area encompasses several units of early Paleozoic age (Guyer and Wilshusen, 1982). Descriptions of the geologic units in the study area are presented in Table 3. Geologic maps of the study watersheds were created in ArcGIS 9.1, by draping a geology layer (Berg et al., 1980) over 1:100,000 scale digital raster graphics (Figures 3-8). Reconnaissance of the study watersheds indicated the presence of extensive surficial, unconsolidated deposits. Valley bottoms display extensive alluvial deposits of sandstone cobbles and boulders, whereas slopes are mantled with colluvium dominated by angular sandstone clasts. The extent of the colluvial deposits likely increased during periglacial climatic episodes experienced in non-glaciated terrains during the Pleistocene Epoch (Mills and Delcourt 1991), when deep freeze-thaw and cryoturbation increased mechanical bedrock disintegration and sediment production (Shultz 1999).

Methodology

Criteria for Selection of Study Reaches

The criteria used to select study reaches for regional curve development include the following:

Formation	Age	Lithology	Max Thickness	Topography
Wills Creek Formation	Silurian	Greenish-gray shale containing localized limestone and sandstone zones.	200 m	Undulating hills of low relief.
Mifflintown Formation	Silurian	Greenish-gray shale interbedded with gray fossiliferous limestone.	90 m	Rolling hills of moderate to high relief.
Bloomsburg Formation	Silurian	Red to grayish-red shale, siltstone, and fine to coarse-grained sandstone with thin impure limestone.	150 m	Rolling hills of moderate relief.
Keefer Formation	Silurian	Gray, medium to thick bedded, fine to coarse-grained, fossiliferous, quartzitic sandstone and hematitic sandstone.	20 m	Hills of moderate to low relief.
Rose Hill Formation	Silurian	Olive to medium-gray shale with interbedded sandy and silty beds.	290 m	Hills of moderate relief.
Tuscarora Formation	Silurian	White to gray, medium to thick bedded, fine to coarse-grained quartzitic sandstone.	460 m	High mountainous ridges and steep, rough terrains.
Juniata Formation	Ordovician	Red, fine-grained to conglomeratic sandstone and to a lesser extent, interbedded red shale.	345 m	High relief, rough mountainous ridges.
Bald Eagle Formation	Ordovician	Fine to coarse-grained, friable, cross-bedded sandstone and quartz pebble conglomerate.	305 m	Mountain ridges and rough to steep topographies.
Martinsburg Formation	Ordovician	Thick sequence of medium to dark-gray to olive-gray shale, interbedded with siltstone and fine-grained sandstone.	3960 m	Dissected valleys with low relief.

Table 3. Bedrock geology units in the study area. Descriptions from Guyer and Wilshusen (1982).

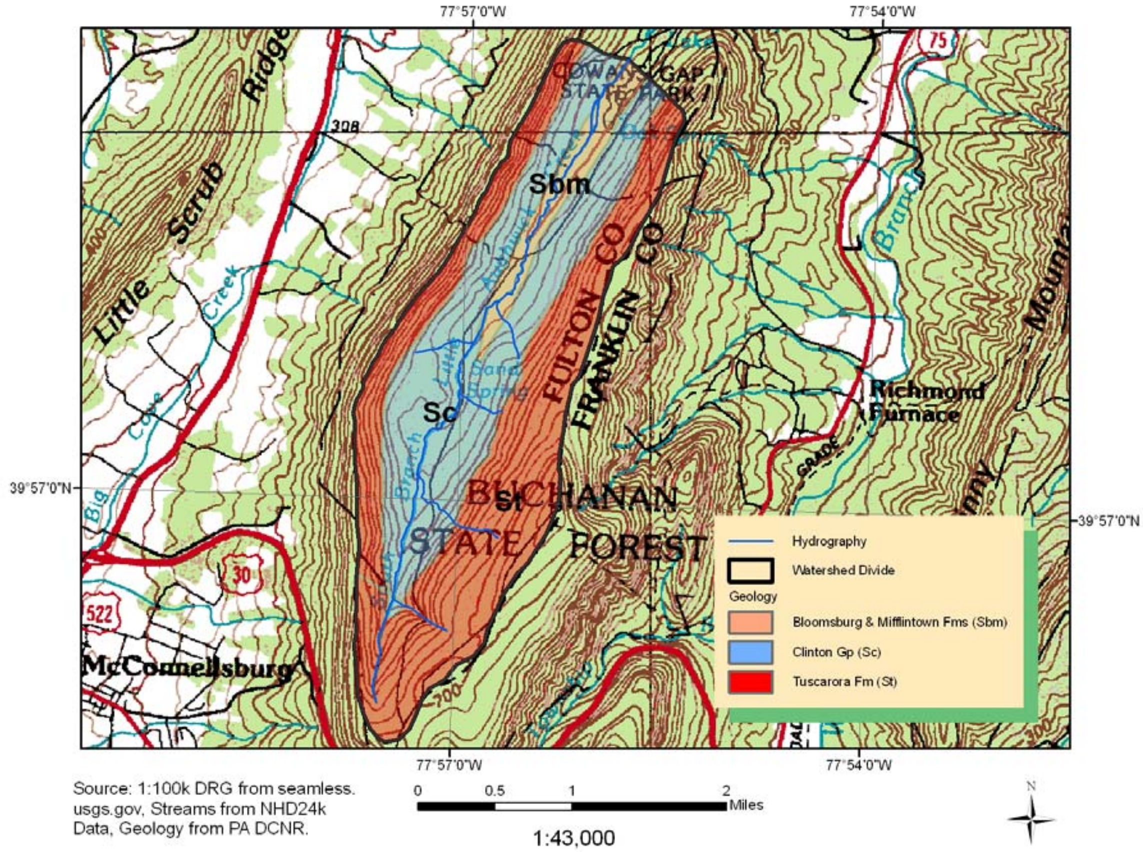

Figure 3. Bedrock geology map of South Branch Little Aughwick Creek Watershed.

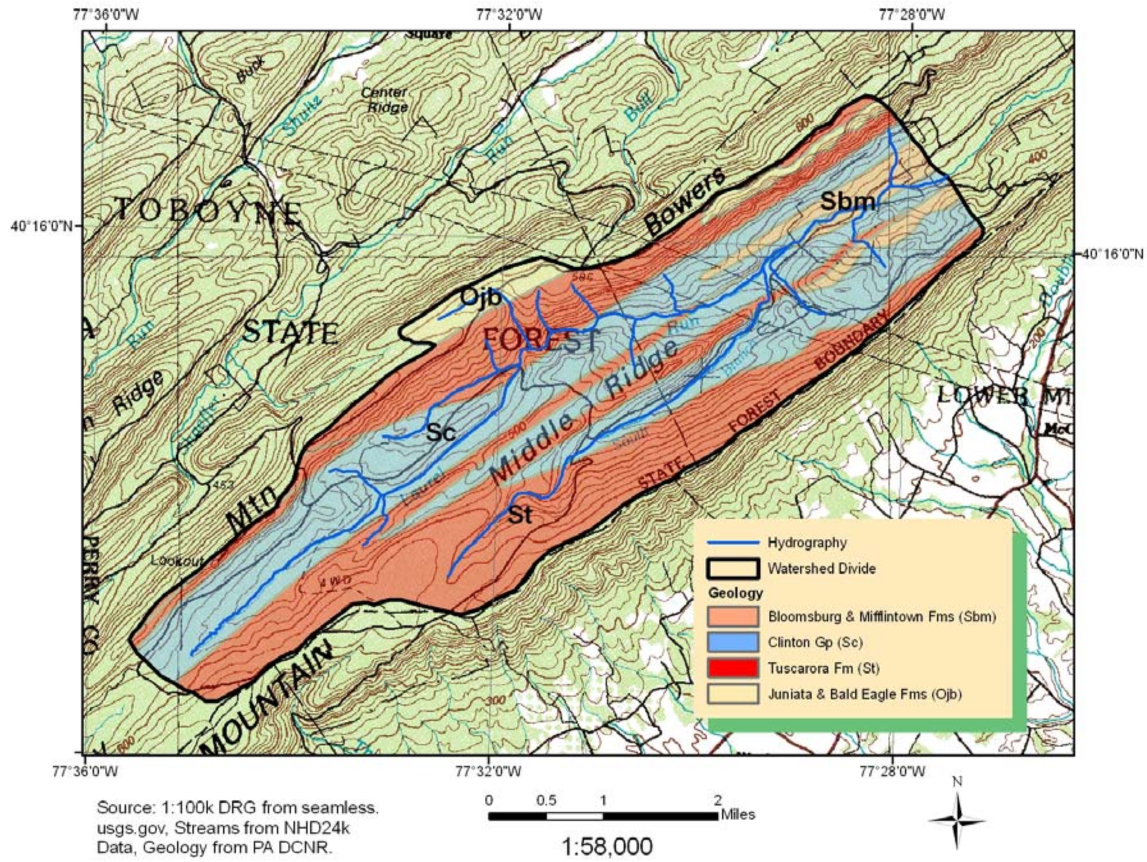

Figure 4. Bedrock geology map of Laurel Run Watershed.

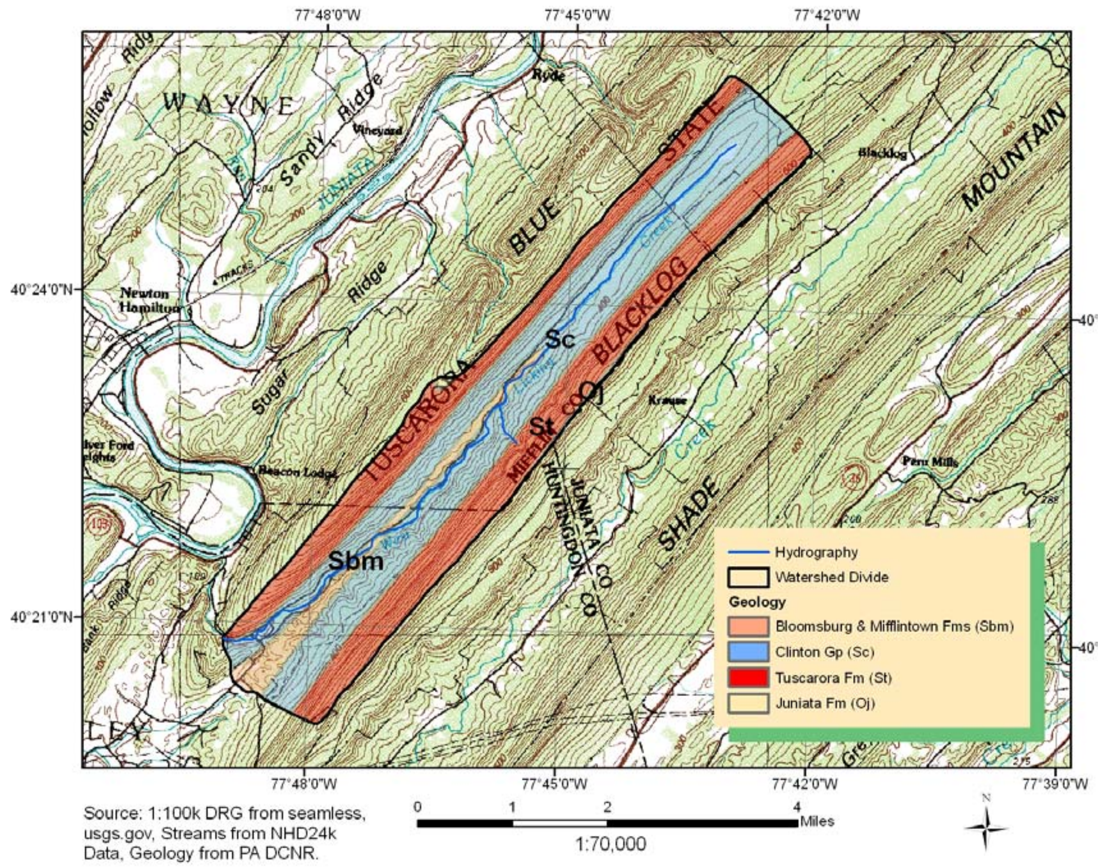

Figure 5. Bedrock geology map of West Licking Creek Watershed.

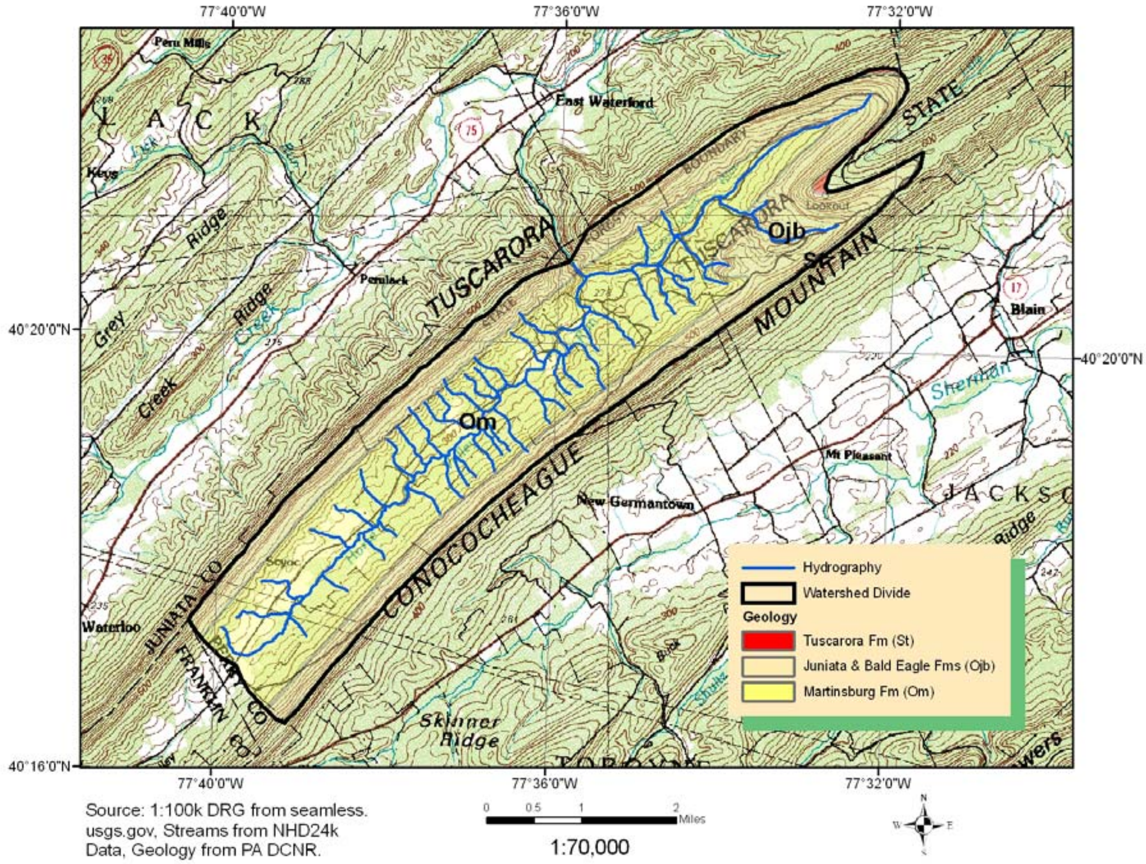

Figure 6. Bedrock geology map of Horse Valley Run.

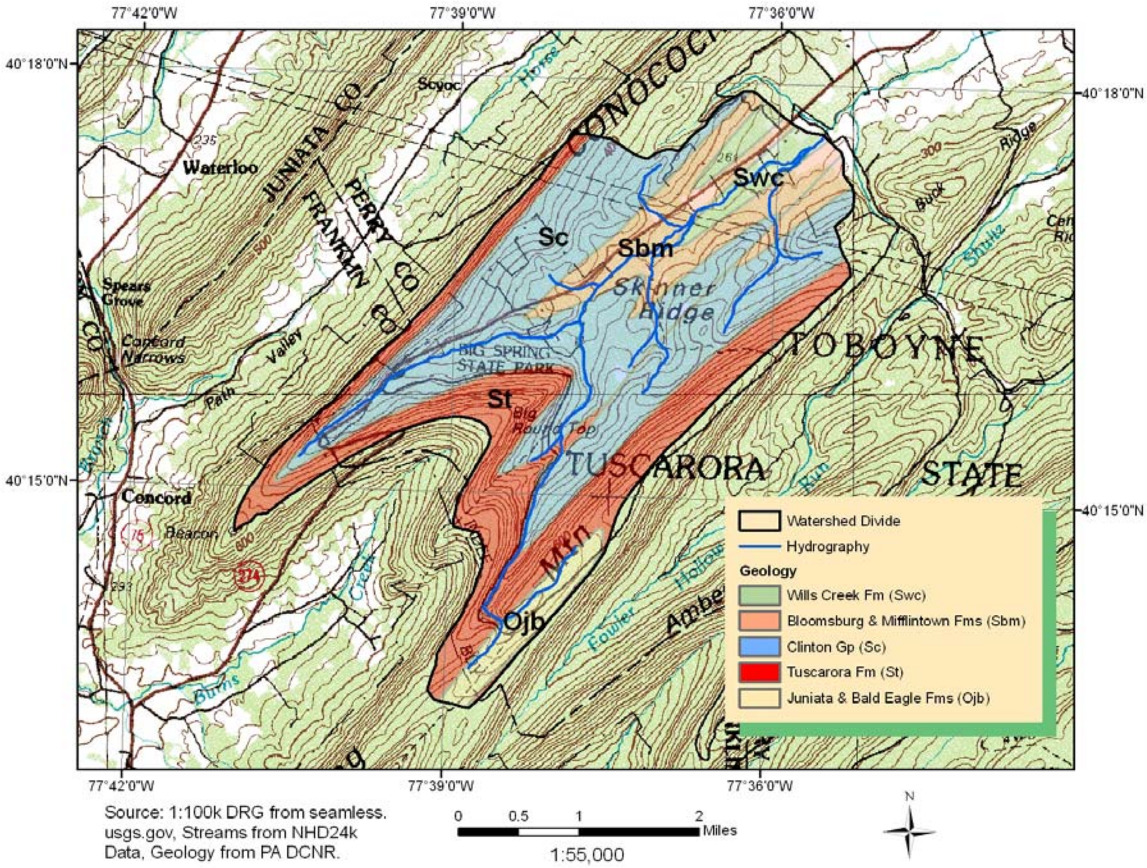

Figure 7. Bedrock geology map of Sherman Creek.

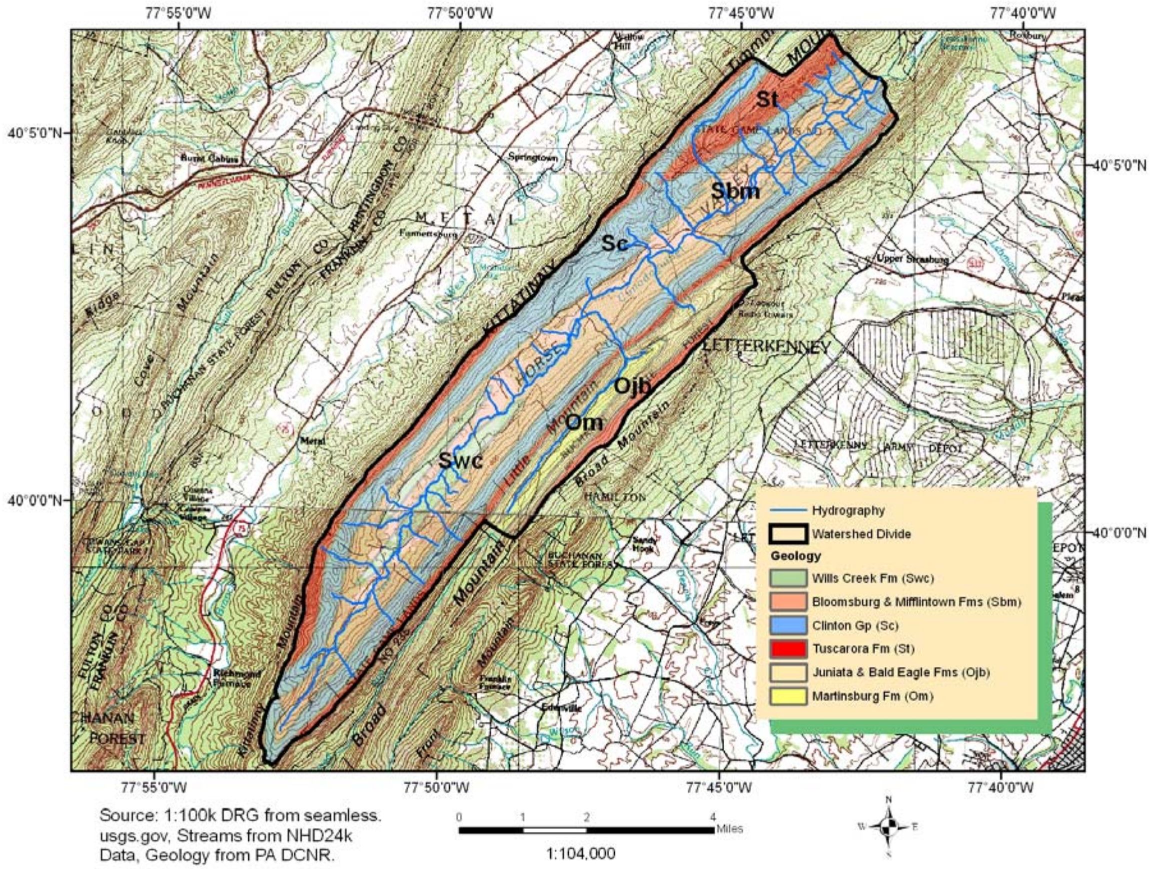

Figure 8. Bedrock geology map of Conodoguinet Creek Watershed.

- The upland areas draining to the study reaches were entirely located within the Ridge and Valley Physiographic Province.
- Surface or sub-surface mining does not occur in the watershed.
- Urban land use was no greater than 20 percent of the total drainage area.
- No more than 20 percent of the watershed above the measured reaches was regulated by flow control structures.
- Less than 30 percent of the total drainage area was underlain by carbonate rocks (i.e. non-carbonate watersheds of Chaplin (2005)).
- The watershed divides above each site were underlain by Silurian Tuscarora or Ordovician Bald Eagle quartz sandstone.

To ensure consistency in reach selection, Chaplin's (2005) criteria were used, with the addition of the constraint on watershed divide geology. Thorough investigation of the study reaches was undertaken to ensure the selection criteria were met. Geographic Information Systems (GIS) were utilized to verify reach selection criteria. After reaches were identified and the stream cross-section surveyed, the watershed area above each measured reach was delineated using ESRI ArcGIS 9.1 and the 7.5' digital raster graphics for each study area. A watershed polygon was manually delineating based upon interpretation of contour lines. After drainage basin polygons were created, basin area was calculated using an area code in ArcGIS 9.1.

To ensure all of the study watersheds were located entirely within the Ridge and Valley Physiographic Province, the study watershed polygons and a shapefile of the physiographic provinces of Pennsylvania were imported into ArcGIS 9.1. Visual inspection of the watershed polygons confirmed the study areas were confined to the Ridge and Valley.

All of the study watersheds were interpreted to have less than 30 percent of their total drainage area underlain by carbonate rocks because the dominant lithology for the geologic formations in each of the watersheds is a clastic sedimentary rock type (Table 3) (Guyer and Wilshusen, 1982). Minor amounts of limestone occur in the Silurian Bloomsburg, Mifflintown, and Wills Creek Formations; however, inspection of the 7.5' topographic maps of the study watersheds revealed no well-developed karst features.

Surface or sub-surface mining activities in the study watersheds was absent as verified by inspecting relevant 7.5' topographic maps and by ground reconnaissance. In addition, the lack of coal bearing strata and significant limestone units in the study watersheds reiterated the absence of any significant mining activities. Regulation of flow on the study streams also was assessed by inspection of topographic maps and ground reconnaissance. All of the study watersheds were determined to be unregulated because no significant dams are mapped above any study reaches.

Urban land use, as defined by Chaplin (2005), consists of low-intensity developed, high-intensity developed, and high-intensity commercial/industrial. Using ArcGIS 9.1, National Land Cover Data (USGS 1996) verified urban land use was less than 20 percent for each study watershed.

Forest lands consist of three unique classifications; deciduous forest, evergreen forest, and mixed forest. National Land Cover Data (USGS 1996) were used to calculate the percent of forest cover in study watersheds. As was the case in determining percent urbanization, the watershed polygons were used to extract land cover type for each watershed in ArcGIS 9.1.

ArcGIS 9.1 was used to verify all of the study watersheds had divides underlain by Silurian Tuscarora Formation or Ordovician Bald Eagle quartz sandstone. The study watershed polygons and a 1:250,000 digital bedrock geology map of Pennsylvania (Berg at al. 1980) were imported into ArcGIS 9.1. Visual inspection of the watersheds verified the Tuscarora or Bald Eagle formations were present along all of the divides.

Development of Regional Curves

Initially, study streams were analyzed by visually inspecting the relevant 7.5' topographic maps. The purpose of this analysis was twofold; to identify land with public access (i.e. state game lands, state parks, or state forest), and identify reaches for later measurements. Measurement reaches displayed widely spaced bottomland contours, suggesting these reaches would display developed floodplains. A minimum of five stable reaches along each study stream was selected for measurement, each stream having two adjacent riffles. Reach stability was visually assessed in the field by ensuring neither aggradation nor degradation of the channel was apparent. Excessive erosion along channel banks, mid-channel bars creating an over-widening effect, and the presence of large woody debris within any reach resulted in exclusion from sampling. Channel cross-sections were surveyed across two adjacent riffles, and values for bankfull cross-sectional area, bankfull mean depth, and bankfull width were calculated for each riffle. The bankfull response variables were calculated using the Reference Reach Spreadsheet v4.3 Level, developed by Mecklenburg (2006) at the Ohio Department of Natural Resources. Average dimensions for the bankfull response variables were calculated for each reach.

The bankfull stage was identified at each riffle prior to survey of the channel cross-section. Riffles were selected for measurement because they are generally free to adjust laterally under the current flow regime and more consistently represent hydraulic geometry (Rosgen 1996). Criteria used to identify the bankfull stage in the field are described by Leopold (1994) and Rosgen (1996), and included the following:

- A change in slope on the channel banks.
- A change in texture of sediments on the channel banks.
- The elevation of the top of the highest depositional feature, such as point bars
- A change in riparian vegetation types and the presence of lichens along the channel banks.

Difficulty in accurately and consistently identifying the bankfull stage arose in the field. To ensure consistency in bankfull stage identification, detailed notes on the four field criteria were made at each site. Channel bank slope breaks were identified as the interface between a surface where the investigator's shoe rested flat up on the floodplain and a surface at the edge of the channel were one's foot rested at an angle. Changes in channel-bank sediments were assessed in the field with a standard grain size comparator. The bankfull stage was identified as the interface between coarse-grained sediment in the channel proper and fine-grained vertically accreted sediments on the floodplain. Fluvial surfaces unrelated to the current hydrologic regime (i.e. terraces) were largely absent from the study reaches. In the case where benches were adjacent to the channel, cross-sectional surveys extended laterally to include the terraces, which allowed for later reassessment of the field-identified bankfull stage.

The channel cross-section was surveyed once the bankfull stage was identified. A plastic measuring tape was stretched taunt across the channel, perpendicular to the direction of flow, and secured above the bankfull stage, all within the riparian corridor. Vertical elevations were determined across the cross-section line using a Leica Rugby 100 LR laser level and a surveying rod fitted with an audible laser receiver. The Leica Rugby 100 LR uses a long range infrared beam and has a vertical accuracy of plus or minus 1.5 mm per 30 m of horizontal distance (Leica 2007).

Cross-sectional surveys were extended laterally as far as possible from the channel. However, dense riparian vegetation made survey beyond the channel margins impossible in several study reaches. Survey measurements were taken every 2.0 feet (0.61 m) in the horizontal direction and at any other locations where a significant change in topography occurred. Bankfull-stage indicators were recorded in surveying to allow subsequent calculation of the bankfull response variables.

Data were assessed to verify they fulfilled the requirements of regression analysis: normally distributed x and y variables, non-autocorrelated and homoscedastic regression residuals, a likely causal relationship between the variables, and a general linear relationship (Donovan 2006). Data normality was determined by performing a Kolmogorov-Smirnov test using the Minitab statistical package. The critical Kolmogorov-Smirnov value was determined at a confidence interval of 95%. If the test statistic was found to be less than the critical value, the sampled data were considered to be normally distributed. As watershed size increases, stream dimensions also increase. Accordingly, a causal relationship between the independent variable, drainage area, and the dependent bankfull response variables was assumed.

Homoscedasticity refers to the condition where residuals are scattered around the regression line in a non-clustered fashion (Donovan 2006). In the case of homoscedasticity, the "variances of the y distributions are all equal to one another" (Kachigan 1986). Homoscedasticity was assessed by visually inspecting the regression plots and observing the location of data points in relation to the best-fit line. Homoscedasticity was not assumed if data points were clustered at one end of the regression line. Non-autocorrelation refers to the condition where residuals are scattered around the regression line randomly (Donovan 2006), and was assessed visually by inspecting the regression plots to ensure data points were randomly scattered around the best-fit line. Non-autocorrelation was not assumed if the data points plotted in groups above or below the regression line.

After the requirements of regression were verified, a regional curve equation relating drainage area to bankfull cross-sectional area, bankfull width, and bankfull mean depth were developed using ordinary least-squares regression. Hydraulic geometry data were compiled in Microsoft Excel and drainage area was plotted versus each of the bankfull response variables on a log-log scale. A power function trend line and the equation describing the best-fit line were added to each of the plots. Two additional statistics were calculated in order to quantify the validity of regression analysis. The coefficient of determination, or R^2 value, quantifies the magnitude of the regression relationship and the f-statistic describes the goodness of fit of the regional curve models (Kachigan 1986). As model fit increases, R^2 values approach 1.0 and f-statistic values approach infinity (Kachigan 1986).

Hydraulic geometry data from the non-carbonate watersheds sampled by Chaplin (2005) were used to develop two additional regional curves. Non-carbonate watersheds draining areas < 75 km^2 and those in the Ridge and Valley Physiographic Province were grouped. The purpose of grouping non-carbonate watersheds sampled by Chaplin (2005) and subsequent regional curve development was to allow for additional comparisons to the lithologically controlled regional curves. Prior to regional curve development, hydraulic geometry data were analyzed to ensure the requirements of regression analysis were met.

Hydraulic geometry data for the lithologically controlled watersheds and all non-carbonate watersheds investigated by Chaplin (2005) were combined to create an additional regional curve. Prior to regional curve development, the hydraulic geometry data were analyzed to ensure they met the prerequisite conditions to perform regression analysis. Regional curves were developed for bankfull cross-sectional area, bankfull width, and bankfull mean depth. The purpose of combining data and subsequently developing another set of regional curves was to assess changes in R^2 values, or regression validity, between the initially developed lithologically controlled regional curves.

A subtle difference in methodology for regional curve development was apparent between this study and Chaplin's (2005), and should be mentioned. Chaplin (2005) sampled several watersheds from across physiographic divides throughout Pennsylvania. In this study, a large number of samples were collected from relatively few watersheds solely in the Ridge and Valley Physiographic Province. As a result of this study's sampling procedure, the issue of statistical independence of the lithologically controlled measured reaches may be apparent, but is not further investigated.

Comparison of Regional Curves

The slope and y-intercept of lithologically controlled regional curve equations were compared to three regional hydraulic geometry curves; (1) regional curves for non-carbonate watersheds (Chaplin 2005), (2) regional curves for non-carbonate watersheds draining areas < 75 km^2, and (3) regional curves for non-carbonate watersheds in the Ridge and Valley Physiographic Province. The equations for the combined regional curve, based on data from this study's lithologically controlled watersheds and all non-carbonate watersheds investigated by Chaplin (2005), were not compared to the lithologically controlled regional curves, due to redundancy in data used to develop both relations. Regional curves were compared using analysis of covariance (ANCOVA), specifically to determine differences in the slope and y-intercept between regional curves. The null hypothesis of the ANCOVA statistical test was that there is no difference in the mean of the slope and y-intercept of the regression equations for both regional curves. The null hypothesis was rejected if the p-value (the probability of incorrectly rejecting the null hypothesis if it is true) was ≤ 0.05 (95% confidence). The analysis was carried out using the Analysis Toolpak add-in for Microsoft Excel. Prior to running the analysis, two variables were created. The first variable (X_2) was given a value of 0 for the control data set and a value of 1 for the discrete data set (Grabow et al. 1998). The second variable ($X_1 * X_2$) was calculated by multiplying the independent variable by the X_2 variable (Grabow et al. 1998). These two variables were generated to allow the regression analysis to test for differences in slope and y-intercept between the data sets.

The ANCOVA was setup using 'before/after' procedures explained by Grabow et al. (1998) to compare unique regression lines. ANCOVA results are reported as p-values and coefficients describing the difference in magnitude between the control and discrete slopes and intercepts.

The R^2 value of the lithologically controlled regional curves was compared individually to the three regional hydraulic geometry curves mentioned above and the combined regional curve, based on data from this study's lithologically controlled and Chaplin's (2005) watersheds. Results of R^2 values illuminate how much variance the independent variable, drainage area, explains in the dependent bankfull response variables. If the R^2 value for the lithologically controlled regional curves were larger, a decrease in variance in the bankfull response variable was apparent. On the contrary, if the R^2 value for the lithologically controlled regional curves were smaller, an increase in variance in the bankfull response variable was apparent.

Bias towards watersheds with relatively small drainage areas was inevitable in this study's development of lithologically controlled regional curves. Standard statistical measures of central tendency, including mean, median, range, and standard deviation, were calculated for drainage area for all regional hydraulic geometry curves. Central tendency analysis for percent watershed urbanization and percent watershed forested for all regional hydraulic geometry curves except the combined curves were made, to assess possible land use bias in the watersheds used to construct regional curves. Any significant bias in drainage area, urbanization, and forest conditions between the lithologically controlled curves will result in constraints in the application of these curves.

Analysis of Channel Sedimentology

Pebble counts were undertaken to illuminate the nature of downstream textural changes in channel bedload sediments in the study streams. A pebble count quantitatively describes the size distribution of bedload sediments in the channel (Rosgen 1996), and was carried out on each surveyed reach. The procedure, initially described by Wolman (1954), and later modified, involved lying a transect across the bed surface in a channel reach (Bunte et al. 2001). Each clast was selected at predetermined intervals along the transect, by blindly picking up the particle at the tip of the measurer's shoe. The intermediate axis of the particle was measured and the clast returned to the stream channel. The process was repeated until the opposite side of the channel was reached. A new transect was then established, in a zig-zag pattern, and the process was repeated until at least 100 measurements were collected. If a riffle were too small to allow 100 measurements, an adjacent riffle was used for additional data.

Pebble-count data were plotted into size classes according to Rosgen (1996). A cumulative frequency plot was constructed by inputting the sedimentology data into the Reference Reach Spreadsheet v4.3 Level (Mecklenburg 2006), and D_{50} and D_{84} particle sizes were calculated. D_{50} refers to a particle size equal to or larger than 50 % of sampled particles (Rosgen 1996). D_{84} refers to a particle size equal to or larger than 84 % of sampled particles, which is the mean particle size plus one standard deviation. D_{50} and D_{84} were plotted versus drainage area for each watershed and for all watersheds. Plots were inspected to assess how particle sizes change in the downstream direction in the study streams.

Results and Interpretations

Regional Curves for Lithologically Controlled Non-Carbonate Watersheds

Hydraulic Geometry Data Analysis

Characteristics of each measured riffle, including coordinate locations, descriptive location information, bankfull stage evidence, and hydraulic geometry data are given in Appendix 1. The reach average of bankfull response variables (Table 4) from 34 unique reaches from the six study watersheds (Figures 9-14), was used in development of lithologically controlled regional curves for non-carbonate watershed in the Ridge and Valley Physiographic Province.

Kolmogorov-Smirnov normality tests (Table 5) show the test statistic for drainage area, bankfull width, and bankfull mean depth are less than the critical value of 0.23; thus, these data sets are normally distributed. The test statistic for bankfull cross-sectional area (Table 5), however, is greater than the critical value of 0.23, so these data cannot be verified as normally distributed. Transformation of bankfull cross-sectional area data to logarithmic scale converts the sample to a normal distribution, but makes later comparison of regional curves impossible. Keaton et al. (2005) suggested in a similar case, transformation of non-normal data to logarithmic scale is not necessary if regression with drainage area provides a high R^2 value and f-statistic value significantly above zero. The bankfull cross-sectional area data set does have a large R^2 value and an f-statistic value significantly above zero (Table 6), and therefore remained untransformed.

Regression residuals plots for all bankfull response variables (Figures 15-17) show the dependent bankfull response variables do not have a constant variance with

Watershed	Reach I.D.	Drainage Area (km^2)	Bankfull XSA (m^2)	Bankfull W (m)	Bankfull MD (m)	D50 (mm)	D84 (mm)	% Urban	% Forested
S. Branch Little Aughwick Creek	1	1.91	0.95	4.54	0.20	9	76	0.00	99.11
S. Branch Little Aughwick Creek	2	5.39	1.94	4.45	0.43	50	130	0.00	95.45
S. Branch Little Aughwick Creek	3	8.86	3.82	7.01	0.56	45	130	0.00	96.88
S. Branch Little Aughwick Creek	4	10.18	4.10	7.19	0.58	23	83	0.00	97.30
S. Branch Little Aughwick Creek	5	12.07	5.09	9.46	0.53	43	160	0.00	97.68
Sherman Creek	6	4.10	2.61	7.06	0.37	59	160	0.00	99.85
Sherman Creek	7	15.39	5.27	10.87	0.49	78	170	0.00	98.58
Sherman Creek	8	4.28	3.36	8.63	0.40	79	180	0.00	96.04
Sherman Creek	9	21.36	5.31	9.94	0.55	94	160	0.00	98.43
Sherman Creek	10	26.05	5.59	9.39	0.61	67	120	0.00	97.79
Sherman Creek	11	2.62	1.37	3.67	0.37	13	84	0.00	93.70
Horse Valley Run	12	11.34	3.54	6.77	0.53	19	70	0.00	88.54
Horse Valley Run	13	36.18	9.88	16.09	0.61	42	130	0.81	94.91
Horse Valley Run	14	12.90	3.68	7.62	0.49	40	120	0.20	99.45
Horse Valley Run	15	10.05	2.96	6.39	0.47	39	90	0.21	99.41
Horse Valley Run	16	7.54	2.36	4.75	0.50	84	130	0.16	99.39
Horse Valley Run	17	3.99	2.18	6.00	0.37	76	140	0.00	99.39
Laurel Run	18	3.70	1.87	5.36	0.35	90	210	0.00	100.00
Laurel Run	19	13.21	4.89	10.10	0.49	77	180	0.00	99.32
Laurel Run	20	1.97	1.54	4.25	0.37	59	130	0.00	100.00
Laurel Run	21	5.49	3.13	5.82	0.53	93	210	0.00	99.79
Laurel Run	22	19.35	4.53	7.18	0.62	93	210	0.00	99.21
Laurel Run	23	28.02	4.93	7.32	0.69	90	210	0.00	99.37
Laurel Run	24	36.23	5.76	12.02	0.46	97	180	0.00	98.63
Conodoguinet Creek	25	73.30	12.11	17.85	0.67	62	120	0.01	94.99
Conodoguinet Creek	26	65.45	13.03	13.99	0.94	58	120	0.00	94.62
Conodoguinet Creek	27	52.58	14.03	16.84	0.85	87	150	0.00	95.04
Conodoguinet Creek	28	41.62	13.37	15.12	0.88	44	97	0.00	93.31
Conodoguinet Creek	29	12.15	4.93	8.43	0.59	48	93	0.00	97.93
West Licking Creek	30	4.30	1.24	4.02	0.30	110	210	0.00	99.14
West Licking Creek	31	6.97	2.08	5.43	0.38	110	200	0.00	99.29
West Licking Creek	32	15.93	4.21	7.25	0.58	120	230	0.00	99.19
West Licking Creek	33	19.32	4.66	8.72	0.53	94	170	0.00	99.25
West Licking Creek	34	26.16	5.77	10.58	0.55	110	230	0.00	99.16

Table 4. Characteristics of sites used to develop lithologically controlled regional curves for non-carbonate watersheds. Key to symbols in table: [XSA] Cross-Sectional Area, [W] Width, [MD] Mean Depth.

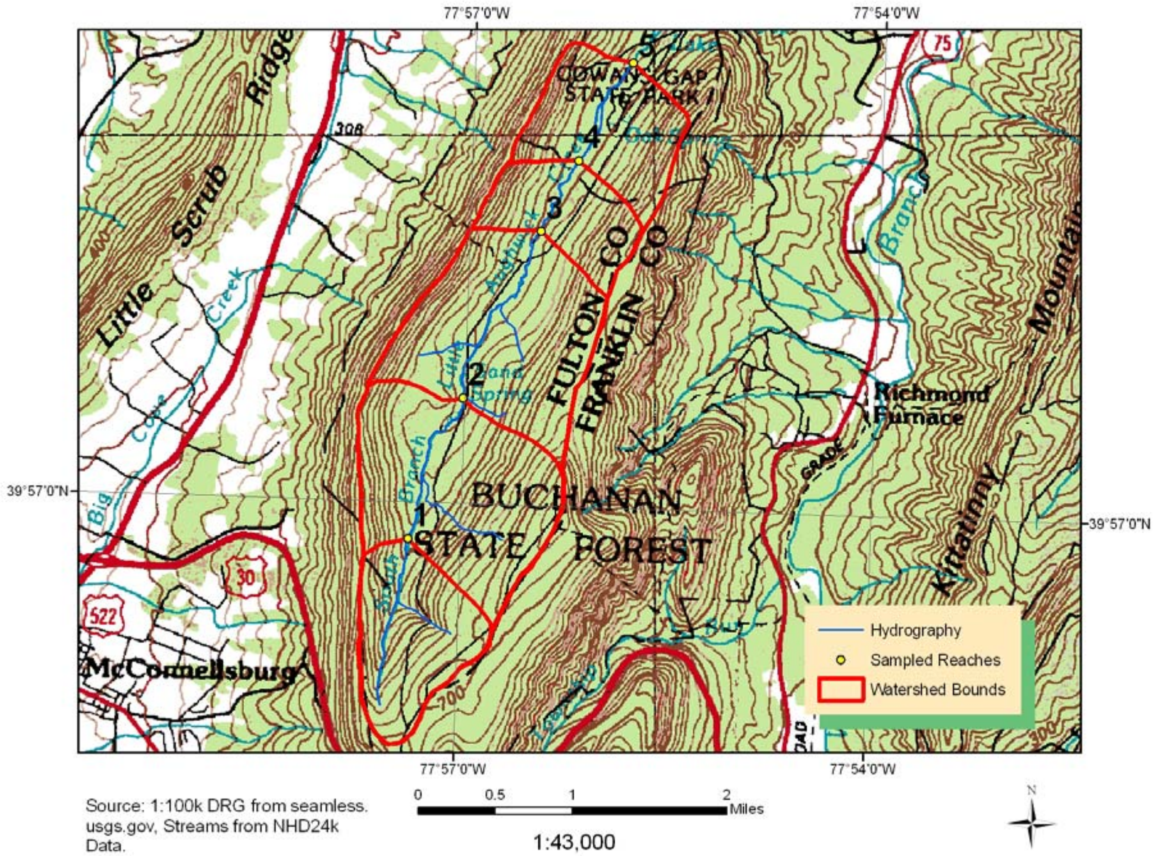

Figure 9. Topographic map showing measured reaches along South Branch Little Aughwick Creek.

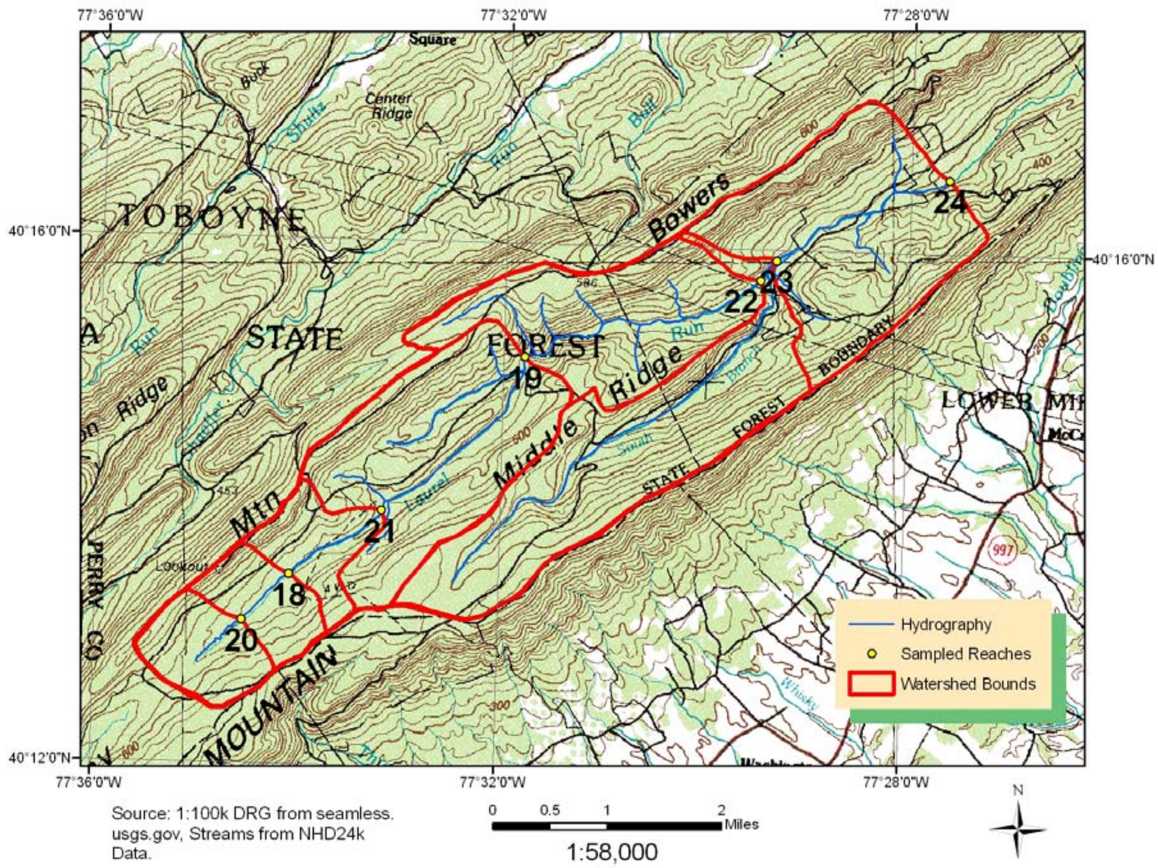

Figure 10. Topographic map showing measured reaches along Laurel Run.

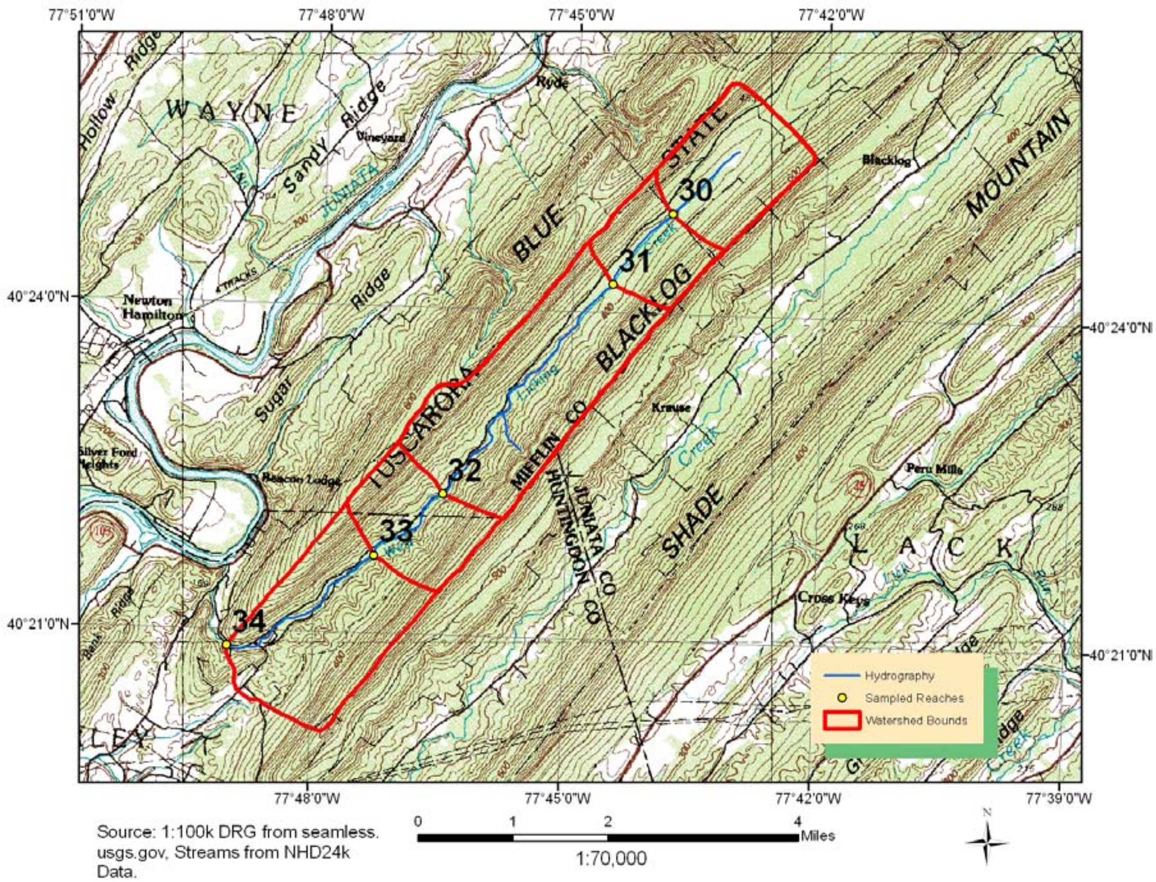

Figure 11. Topographic map showing measured reaches along West Licking Creek.

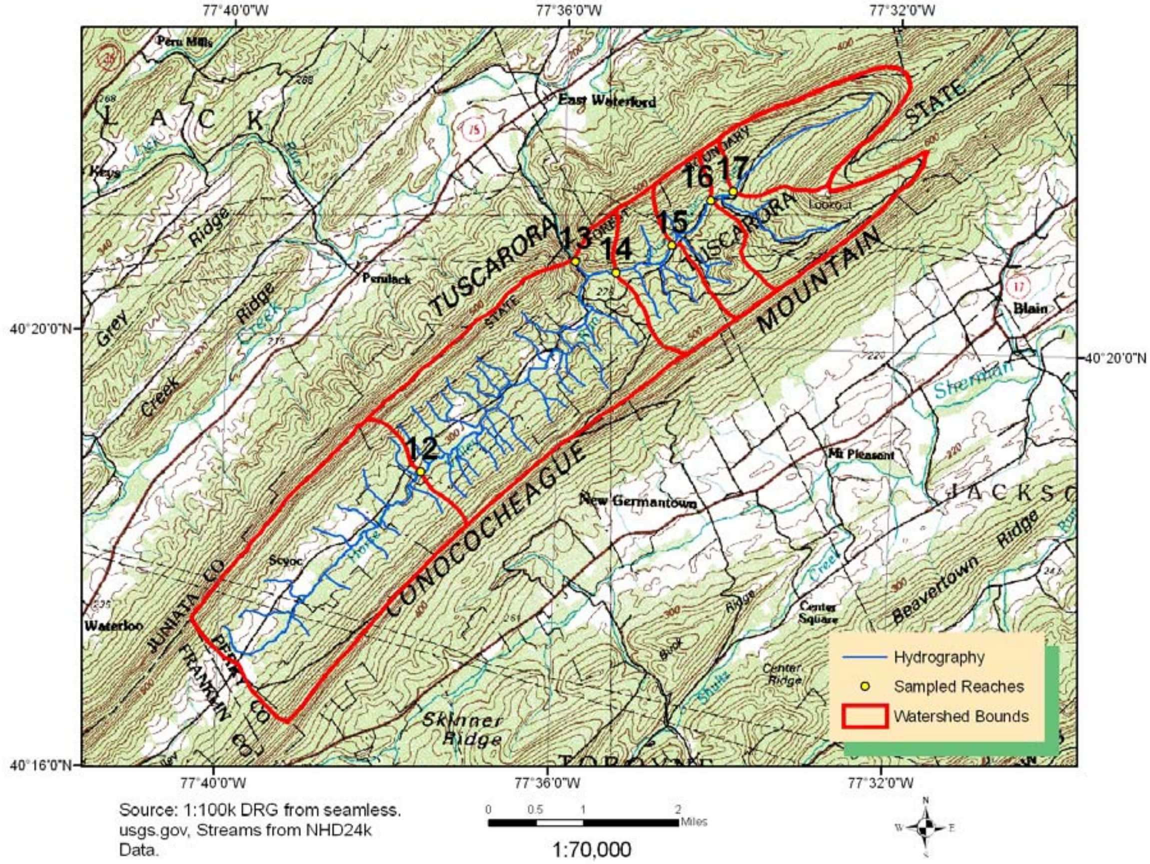

Figure 12. Topographic map showing measured reaches along Horse Valley Run.

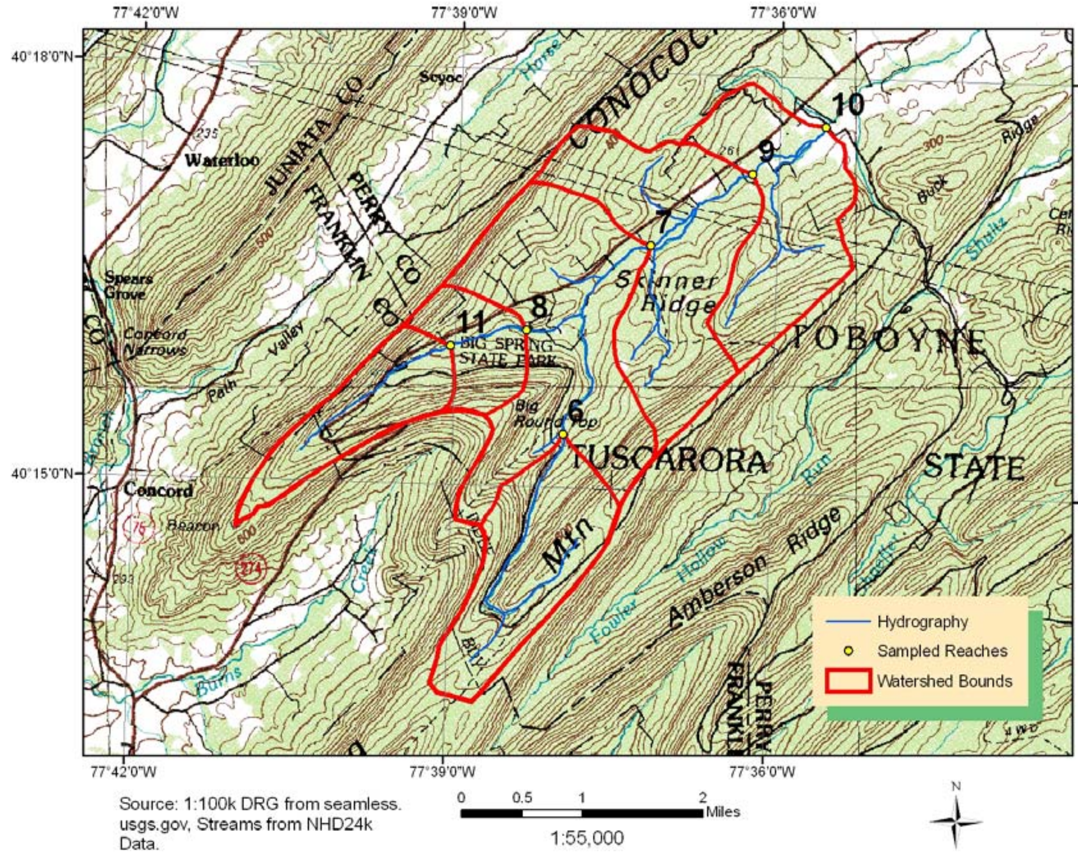

Figure 13. Topographic map showing measured reaches along Sherman Creek.

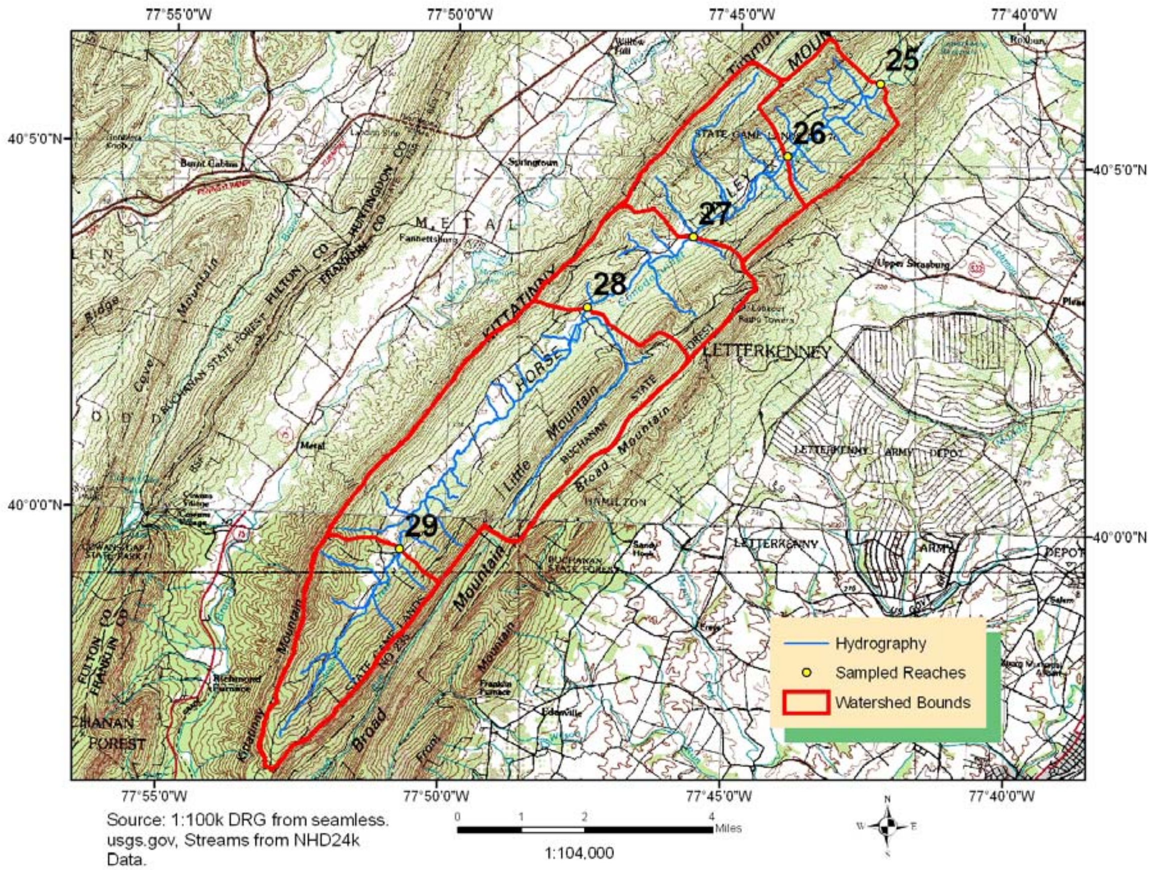

Figure 14. Topographic map showing measured reaches along Conodoguinet Creek.

Sample Description	Kolmogorov-Smirnov Test Statistic
Drainage Area	0.199
Cross-Sectional Area	0.254
Width	0.155
Depth	0.119

Table 5. Kolmogorov-Smirnov normality test statistics for lithologically controlled regional curves for non-carbonate watersheds. A sample size (n) = 34 yields a critical value of 0.23.

Response Variable	Equation	Slope	Y Intercept	R^2	F-statistic
Cross-Sectional Area	$CSA=0.791DA^{0.649}$	0.649	0.791	0.88	633.90
Width	$W=3.061DA^{0.380}$	0.380	3.061	0.78	229.90
Mean Depth	$D=0.256DA^{0.273}$	0.273	0.256	0.73	134.72

Table 6. Summary of quantitative attributes for lithologically controlled regional curves for non-carbonate watersheds.

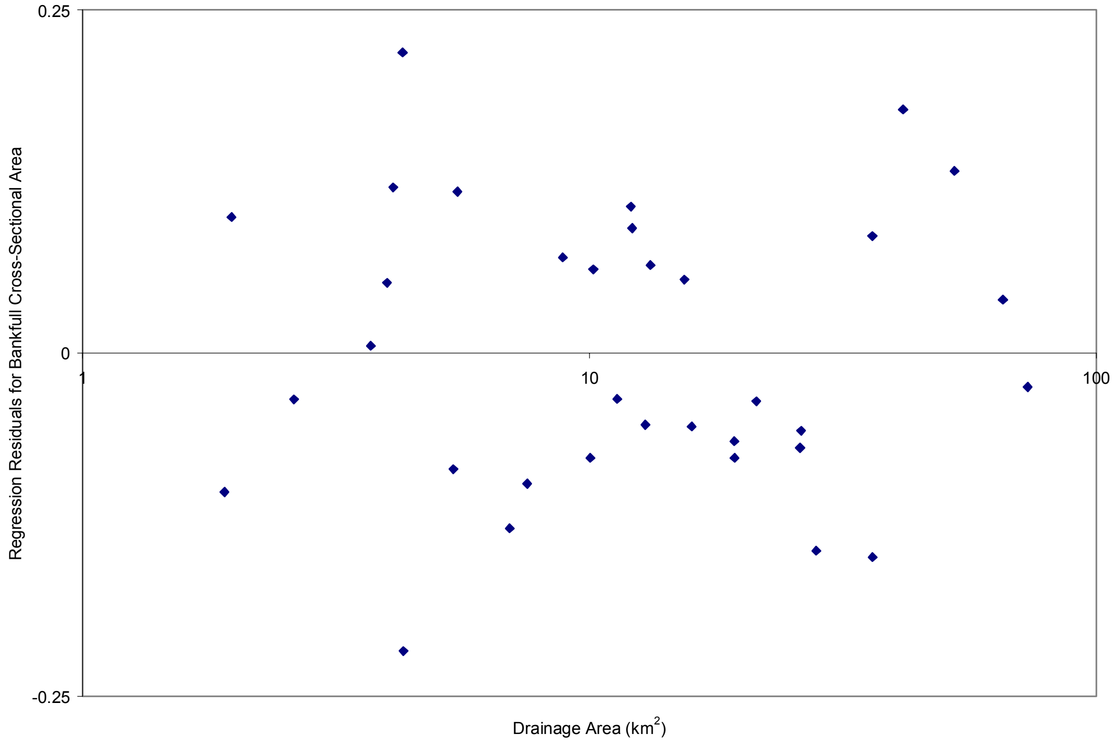

Figure 15. Regression residuals plot for bankfull cross-sectional area for lithologically controlled regional curves for non-carbonate watersheds.

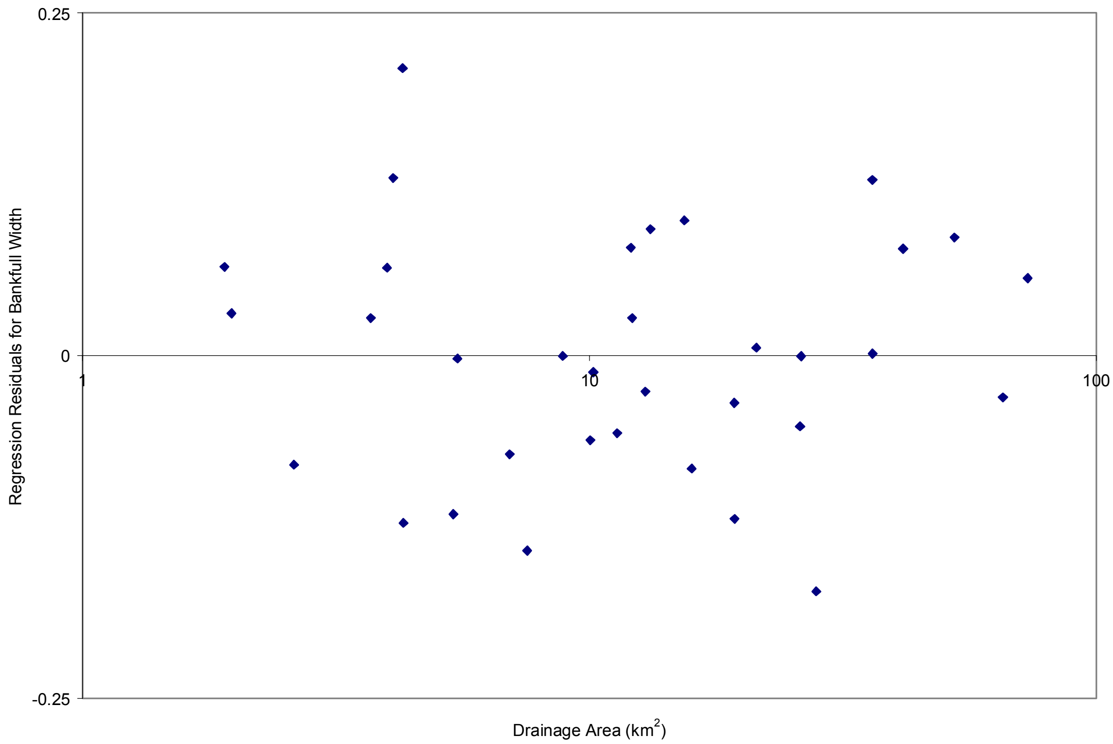

Figure 16. Regression residuals plot for bankfull width for lithologically controlled regional curves for non-carbonate watersheds.

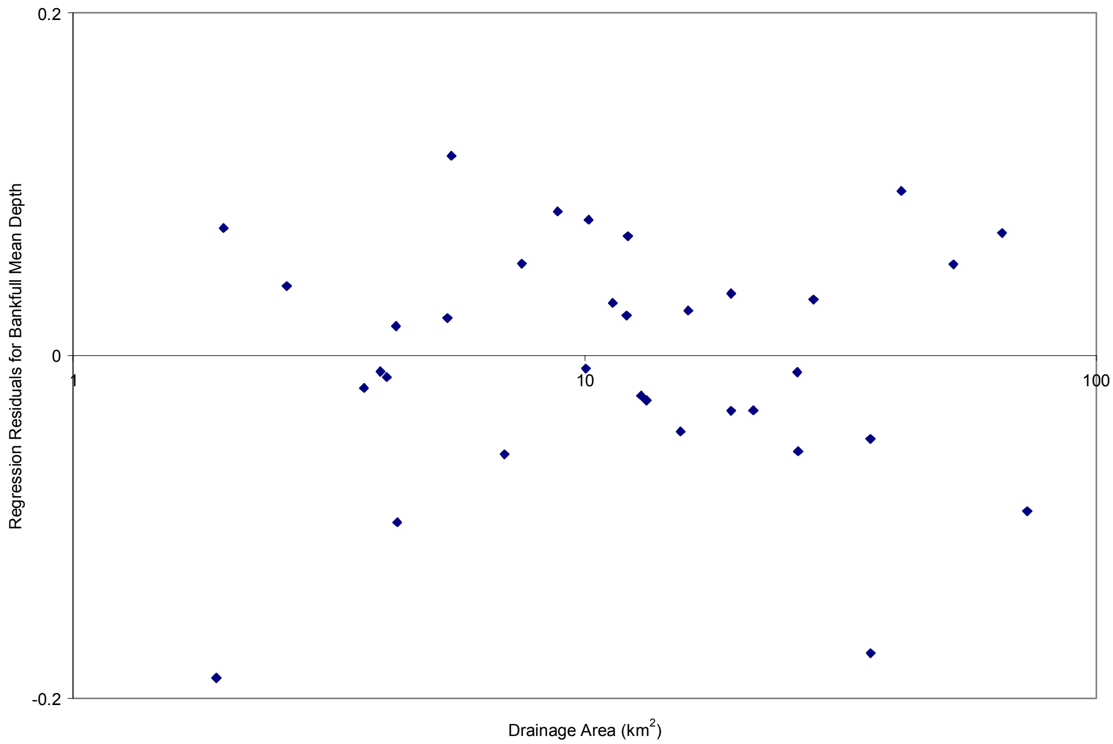

Figure 17. Regression residuals plot for bankfull mean depth for lithologically controlled regional curves for non-carbonate watersheds.

respect to the independent variable, drainage area. This condition, referred to as heteroscedasticity, violates a requirement of regression analysis. Due to inherent variability in the hydraulic geometry of mountain streams, a constant variance of the dependent bankfull response variables is not expected. Further visual inspection of the plots shows the residuals are randomly distributed around the regression line. The lack of distinctive grouping of the residuals verifies the sampled data is non-autocorrelated. The last two requirements to perform regression analysis, a causal and linear relationship between the independent and dependent variables are assumed.

Regional Curve Development

The bankfull cross-sectional area regional curve (Figure 18) has the largest R^2 value, 0.88, followed by bankfull width (Figure 19) and bankfull mean depth (Figure 20) values of 0.78 and 0.73, respectively (Table 6). The f-statistic value for the bankfull cross-sectional area regional curve is highest, 232.73, followed by bankfull width and bankfull mean depth values of 110.29 and 88.13, respectively (Table 6). Thus, the bankfull cross-sectional area regional curve displays the least variance and best fit, followed by bankfull width and lastly bankfull mean depth, as evidenced by R^2 and f-statistic values (Table 6).

Comparison of Regional Curves

The p-values (Table 7) show a statistically different slope and y-intercept exists between the bankfull cross-sectional area regional curves for lithologically controlled regional curves for non-carbonate watersheds and Chaplin's (2005) curves for non-carbonate watersheds. The p-value and coefficient for y-intercept for bankfull

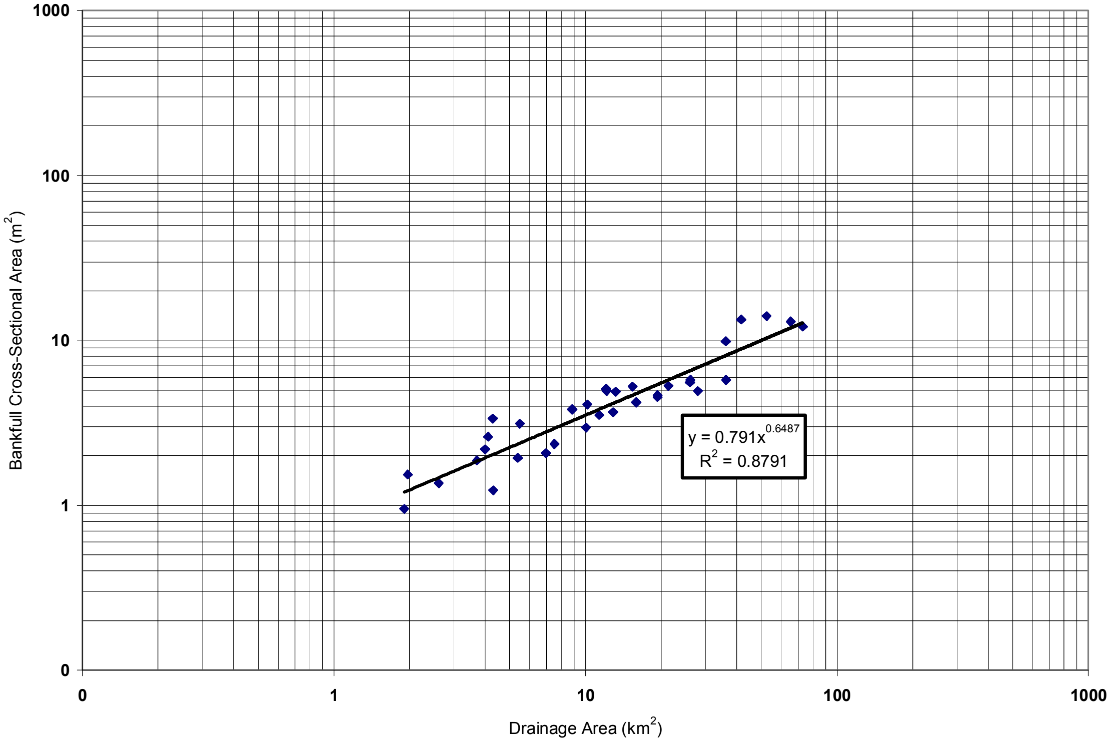

Figure 18. Lithologically controlled regional curve for non-carbonate watersheds for bankfull cross-sectional area.

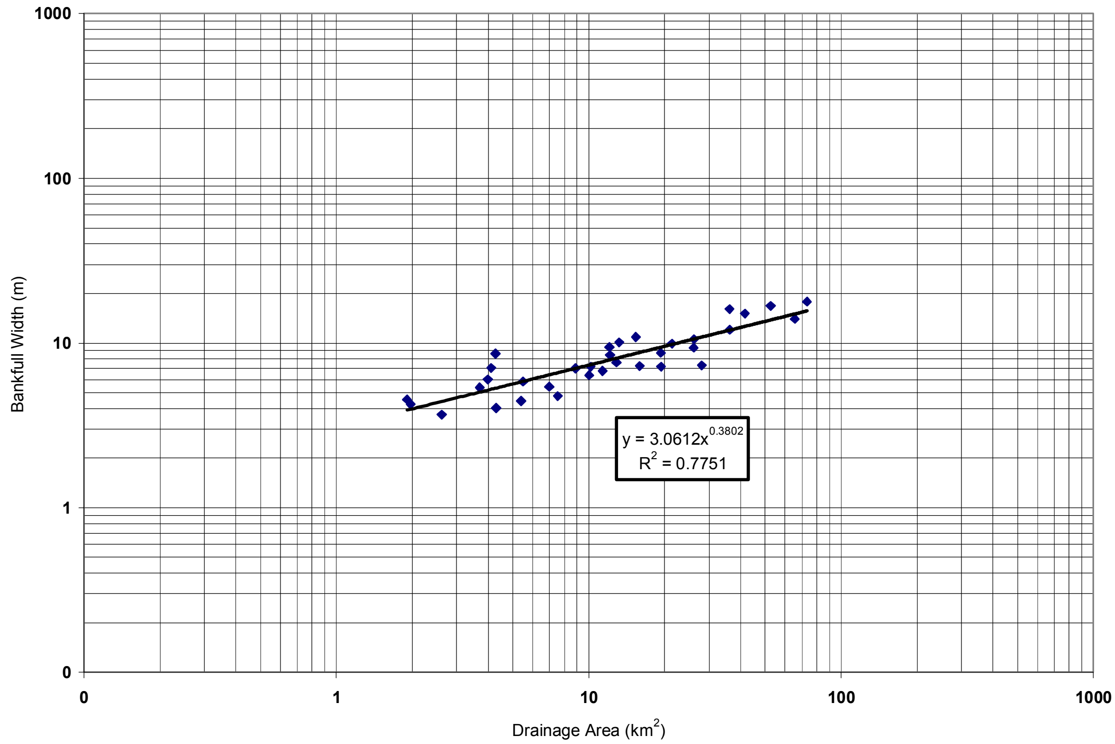

Figure 19. Lithologically controlled regional curve for non-carbonate watersheds for bankfull width.

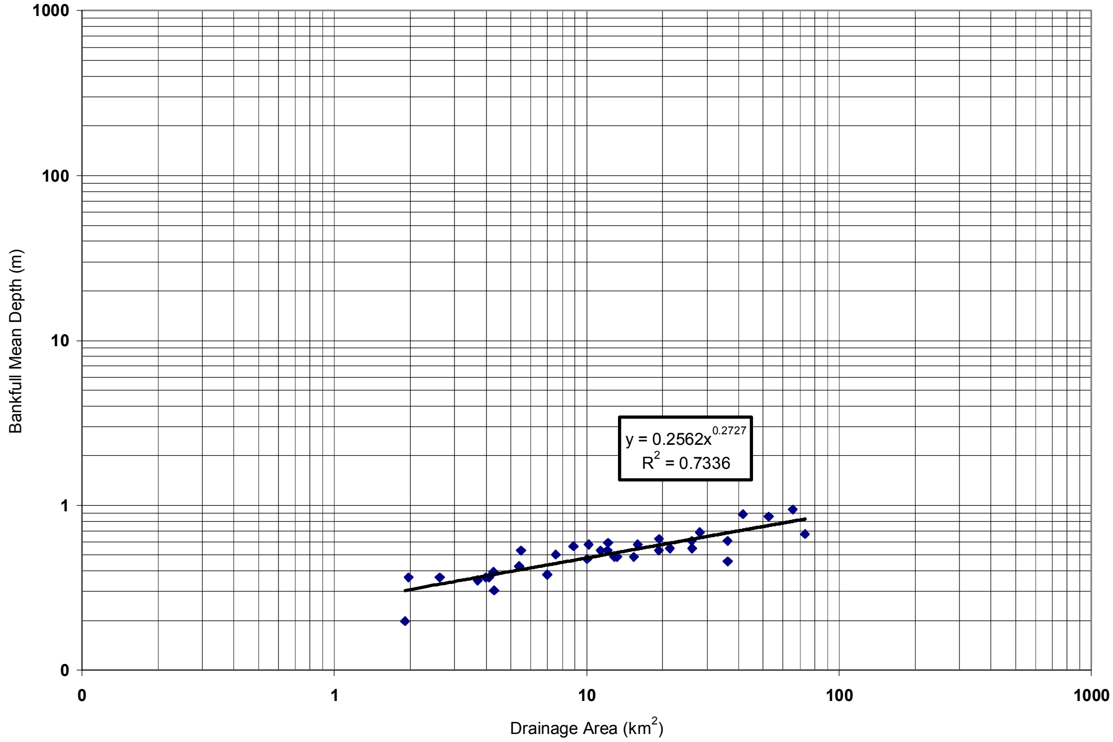

Figure 20. Lithologically controlled regional curve for non-carbonate watersheds for bankfull mean depth.

Bankfull Cross-Sectional Area (m^2)						
			Intercept	**Intercept**	**Slope**	**Slope**
Data	**N**	**R^2**	**p-value**	**Coefficient**	**p-value**	**Coefficient**
Controlled Curves	34	0.88	0.031	0.179	0.008	-0.148
Chaplin's Curves	55	0.92	---	---	---	---
Bankfull Width (m)						
			Intercept	**Intercept**	**Slope**	**Slope**
Data	**N**		**p-value**	**Coefficient**	**p-value**	**Coefficient**
Controlled Curves	34	0.78	0.777	0.021	0.166	-0.069
Chaplin's Curves	55	0.81	---	---	---	---
Bankfull Depth (m)						
			Intercept	**Intercept**	**Slope**	**Slope**
Data	**N**		**p-value**	**Coefficient**	**p-value**	**Coefficient**
Controlled Curves	34	0.73	0.083	0.119	0.204	-0.058
Chaplin's Curves	55	0.72	---	---	---	---

Table 7. Statistical results from analysis of covariance comparison between lithologically controlled curves and Chaplin's (2005) curves.

cross-sectional area is 0.031 and 0.179 (Table 7). The p-value and coefficient for slope for the bankfull cross-sectional area curve is 0.008 and -0.148 for slope (Table 7). Thus, the lithologically controlled regional curve for non-carbonate watersheds for bankfull cross-sectional area has a slightly higher y-intercept and slightly lower slope, than Chaplin's (2005) bankfull cross-sectional area curve. Bankfull width and bankfull mean depth regional curve y-intercepts and slopes have p-values greater than 0.05, and therefore can not be shown to be statistically different. As a result, this study's hypothesis that regional curves developed for small mountain streams with abundant coarse sandstone alluvium will produce wider and shallower dimensions in comparison to curves developed for whole physiographic provinces, must be rejected.

Coefficient of determination (R^2) values for both curves (Table 7) reveal the bankfull cross-sectional area regional curves have the largest R^2 values, with a value of 0.92 for Chaplin's (2005) curves and 0.88 for the lithologically controlled curves. R^2 values for the bankfull width regional curves are 0.81 for Chaplin's (2005) curves and 0.78 for the lithologically controlled curves. Accordingly, drainage area explains more variance in bankfull cross-sectional area and bankfull width for Chaplin's (2005) regional curves. The bankfull mean depth curves have R^2 values of 0.73 for the lithologically controlled curves and 0.72 for Chaplin's (2005) curves. Overall, only minor differences in R^2 values and, therefore, regression validity, exist between both regional curves.

Drainage area statistics (Table 8) reveals the watersheds used to construct lithologically controlled curves are on average much smaller than those used to construct Chaplin's (2005) curves. The mean drainage area for sites used to develop the lithologically controlled curves was 18.2 km^2, compared to a mean of 164.2 km^2 for sites

Regional Curve Description	Samples	Mean	Median	Range	Standard Deviation
Lithologically Controlled Regional Curves	34	18.2	12.1	1.91 - 73.3	17.9
Chaplin's Regional Curves	55	164.2	119.7	8.93 - 554.3	148.6
Ridge & Valley Regional Curves	18	221.6	135.1	13.7 - 554.3	177.3
< 75 km^2 Regional Curves	19	32.7	30.6	8.92 - 72.5	18.5
Combined Regional Curves	89	108.4	41.6	1.91 – 554.3	137.0

Table 8. Central tendency statistics for watershed drainage area of regional curves. Statistics calculated for lithologically controlled regional curves, Chaplin's (2005) regional curves, regional curves for watersheds < 75 km2, regional curves for the Ridge and Valley, and combined regional curves. Drainage area units are in km^2.

in Chaplin's (2005) curves. A greater range (Table 8) of drainage areas was sampled to construct Chaplin's (2005) curves.

Means for percent watershed urbanized for regional curves (Table 9) shows both are derived from watersheds having very minimal urban land use. The mean of percent watershed urbanized for lithologically controlled curves was 0.04%, compared to 1.63% for Chaplin's (2005) curves. Watersheds with a broader range in urbanized conditions were sampled to construct Chaplin's (2005) regional curves. Lithologically controlled curves are derived from heavily forested watersheds, displaying on average 97.7% forest cover, whereas Chaplin's (2005) curves were constructed from watersheds with a mean of only 64.4% forest cover (Table 10).

Interpretations

Analysis shows the lithologically controlled regional curve for bankfull cross-sectional area has a statistically different slope and y-intercept than Chaplin's (2005). Bedrock geology, geologic structure, physiography, channel gradient, watershed size, riparian vegetation, and land-use conditions may influence differences in the slope and y-intercept of the regional curves. Bedrock geology is similar in this study's watersheds, but, in contrast, the bedrock geology of Chaplin's (2005) watersheds consists of a much broader range of lithologies (Sevon 2000).

Differences are apparent in physiography of the watersheds used to construct both regional curves. Lithologically controlled curves in this study are derived solely from watersheds in the Ridge and Valley Physiographic Province; on the contrary, Chaplin's (2005) curves come from watersheds located in several physiographic provinces.

Regional Curve Description	Samples	Mean	Median	Range	Standard Deviation
Lithologically Controlled Regional Curves	34	0.04	0.00	0.00 – 0.81	0.15
Chaplin's Regional Curves	55	1.63	0.80	0.00 – 19.0	3.45
Ridge & Valley Regional Curves	18	1.63	1.15	0.00 – 5.80	1.71
< 75 km^2 Regional Curves	19	1.45	0.10	0.00 – 15.0	3.68

Table 9. Central tendency statistics for percent watershed urbanized of regional curves. Statistics calculated for lithologically controlled regional curves, Chaplin's (2005) regional curves, regional curves for watersheds < 75 km^2, and regional curves for the Ridge and Valley. Values calculated without data for six watersheds for Chaplin's (2005) curves.

Regional Curve Description	Samples	Mean	Median	Range	Standard Deviation
Lithologically Controlled Regional Curves	34	97.7	98.9	88.5 – 100.0	2.55
Chaplin's Regional Curves	55	64.4	64.0	20.0 – 100.0	21.1
Ridge & Valley Regional Curves	18	58.4	67.5	31.0 – 83.0	18.3
< 75 km^2 Regional Curves	19	64.3	63.0	20.0 – 99.0	24.4

Table 10. Central tendency statistics for percent watershed forested of regional curves. Statistics calculated for lithologically controlled regional curves, Chaplin's (2005) regional curves, regional curves for watersheds < 75 km2, and regional curves for the Ridge and Valley. Values calculated without data for six watersheds for Chaplin's (2005) curves.

Geological structure and surface processes vary across physiographic provinces (Sevon 2000), potentially influencing the slope and y-intercept of regional curves. For instance, the Ridge and Valley Physiographic Province that hosts this study's sites is dominated by fluvial erosion and relict periglacial mass wasting (Sevon 2000), while Chaplin's (2005) study also includes areas of glacial erosion and deposition.

Based upon field observations, channel gradients are high and might be greater in the watersheds used to construct lithologically controlled curves. The lithologically controlled watersheds are located in mountainous areas characterized by high gradient riffles and lower gradient pools. Observation of adjacent riffles in the lithologically controlled watersheds suggests significant variability in slope exists. As channel gradient increases, velocity does the same, possibly resulting in significant local differences in discharge between successive riffles. Variability in discharge between riffles of differing gradient may result in different channel-forming discharges for riffle sections within a single reach, and therefore impact channel form, and the resultant regional curves. On the contrary, channel gradient is likely lower and less variable on the lowland rivers sampled by Chaplin (2005), so stream flows would be more uniform, leading to less variable channel dimensions.

Watersheds used to construct Chaplin's (2005) curves are on average much larger and consist of a wider range in drainage areas than those in this study. Accordingly, much of the difference in slope and y-intercept of the regression lines may be due to data that is not common to both studies. For instance, the smaller drainage areas of this study's lithologically controlled curves and the larger drainage area of Chaplin's (2005) curves may have a considerable influence on their respective regression lines. In addition, smaller watersheds are prone to a flashier hydrologic regime in comparison to larger watersheds. Rapid delivery of precipitation to stream channels in small watersheds is the result of steep slopes that transition from ridges. On the contrary, larger watersheds generally have gentler slopes and as a result, precipitation takes a longer time to be delivered to channels.

Land use, including the impacts of urbanization and deforestation, can alter runoff processes and change flood frequency (Wohl 2000). Urbanization and deforestation results in an increase in the production of hill slope sediment and a decrease in infiltration, resulting in an increase in water yield (Wohl 2000). The lithologically controlled regional curves and Chaplin's (2005) curves are both derived from dominantly rural watersheds, so the percent of urban land probably does not significantly influence the relations. However, the percent of forestation, does vary significantly between watersheds used in the two regional curves and might influence the slope and y-intercept of the curves. Lithologically controlled regional curves are derived from watersheds almost entirely forested; while watersheds used to construct Chaplin's (2005) curves are on average approximately two-thirds forested.

Riparian vegetation is an important factor in determining the strength of channel banks (Knighton 1998) and thus, influences channel dimensions. Vegetation at most lithologically controlled sites has forest cover, with a few located in grasslands or pastures. Chaplin (2005) did not mention riparian vegetation for his non-carbonate watersheds, but differences in riparian vegetation type and vegetation density between regional curves may exist and may yield differences in the attributes of curves.

The factors influencing differences in R^2 values between regional curves may include the number of sites used in curve development, watershed size, and channel gradient. Twenty-one fewer sites were used to construct the lithologically controlled regional curves than were used to construct Chaplin's (2005) curves. As sample size increases, the precision of any statistical test increases (Kachigan 1986). In this case, Chaplin's (2005) curves for bankfull cross-sectional area and bankfull width have larger R^2 values and less variance versus the lithologically controlled curves, possibly in large part as a result of a larger sample size.

Channel gradient is steeper along small mountain streams and floodplains are not as well developed as they are in lowland settings. Correct identification of the bankfull stage is a prerequisite when sampling watersheds to develop regional curves. Therefore, difficulty in accurately identifying the floodplain in high-gradient mountain streams may result in hydraulic geometry relationships with more variance. Curves developed with lowland rivers, with better developed and easier to identify floodplains, likely should show less variance. Furthermore, smaller streams may be more difficult to survey precisely because the intricacies of channel form are more subtle. Thus, surveying error in small channels may result in greater relative errors in calculation of the bankfull response variables, than would occur on larger channels.

Regional Curves for Non-carbonate Watersheds Draining Areas < 75 km^2

Hydraulic Geometry Data Analysis

The characteristics of 19 streams draining non-carbonate watersheds (Table 11), initially investigated by Chaplin (2005), were used in the development of regional curves for watersheds draining areas < 75 km^2 in the Piedmont, Ridge and Valley, Appalachian

USGS Gage I.D.	Physiographic Province	Drainage Area (km^2)	Bankfull XSA (m^2)	Bankfull W (m)	Bankfull MD (m)	Percent Urban	Percent Forested
1516500	a	31.60	14.12	21.70	0.76	0.1	47
1533250	a	30.56	7.46	17.80	0.32	0.2	63
1542720	a	21.60	4.31	8.56	0.52	0	65
1542810	a	13.57	3.98	13.53	0.41	0	99
1552500	a	61.64	20.44	20.88	0.98	0	92
1567500	v	38.85	10.03	13.17	0.77	0.1	49
1569340	v	13.70	6.55	12.62	0.53	1.9	34
1613050	v	27.71	6.22	11.09	0.57	0	70
3026500	a	20.31	7.51	10.91	0.70	0.1	94
3039925	a	8.94	3.14	8.32	0.38	0.1	99
3049800	a	14.97	3.03	5.49	0.55	0	80
3072880	a	45.32	16.17	17.53	0.93	1.4	63
4213075	cl	11.53	2.24	8.87	0.26	---	---
1472199	p	59.57	18.77	29.41	0.64	1.9	61
1475850	p	40.92	14.96	17.53	0.85	15	61
1480300	p	48.43	11.89	17.50	0.68	1.5	31
1578200	p	22.53	5.92	8.90	0.68	0.9	20
1586210	p	36.26	9.85	13.53	0.73	---	---
1586610	p	72.52	17.56	20.79	0.84	---	---

Table 11. Characteristics of sites used to develop regional curves for non-carbonate watersheds < 75 km2. Key to symbols in table: [XSA] Cross-Sectional Area, [W] Width, [MD] Mean Depth, [v] Ridge and Valley, [a] Appalachian Plateaus, [cl] Central Lowland, [p] Piedmont, [---] missing data.

Plateaus, and Central Lowland Physiographic Provinces in Pennsylvania and selected areas of Maryland.

Kolmogorov-Smirnov normality tests (Table 12) for drainage area and all bankfull response variables show all test statistics are less than the critical value of 0.3, and thus the data are normally distributed. Plots of regression residuals for bankfull response variables (Figures 21-23) reveal the variances are not all equal, resulting in heteroscedasticity. The residuals plots show no distinctive grouping above or below the regression line, suggesting the residuals are randomly distributed about the regression line, and non-autocorrelation is assumed. The last two requirements to perform regression analysis, a causal and linear relationship between the independent and dependent variables also are assumed.

Regional Curve Development

R^2 values for bankfull cross-sectional area (Figure 24), bankfull width (Figure 25), and bankfull mean depth (Figure 26) are 0.846, 0.607, and 0.536, respectively (Table 13). R^2 values for bankfull width and bankfull mean depth regional curves are significantly lower than 1.0, indicating a large amount of variance is unexplained. F-statistic values for bankfull cross-sectional area, bankfull width, and bankfull mean depth (Table 13) are rather low; confirming a large amount of variance is unexplained in these curves. The bankfull cross-sectional area regional curve displays the least variance and best fit, followed by bankfull width and, lastly, bankfull mean depth, as evidenced by R^2 and f-statistic values.

Sample Description	Kolmogorov-Smirnov Test Statistic
Drainage Area	0.129
Cross-Sectional Area	0.173
Width	0.126
Depth	0.108

Table 12. Kolmogorov-Smirnov normality test statistics for regional curves for streams in non-carbonate watersheds < 75 km2. A sample size (n) = 19 yields a critical value of 0.3.

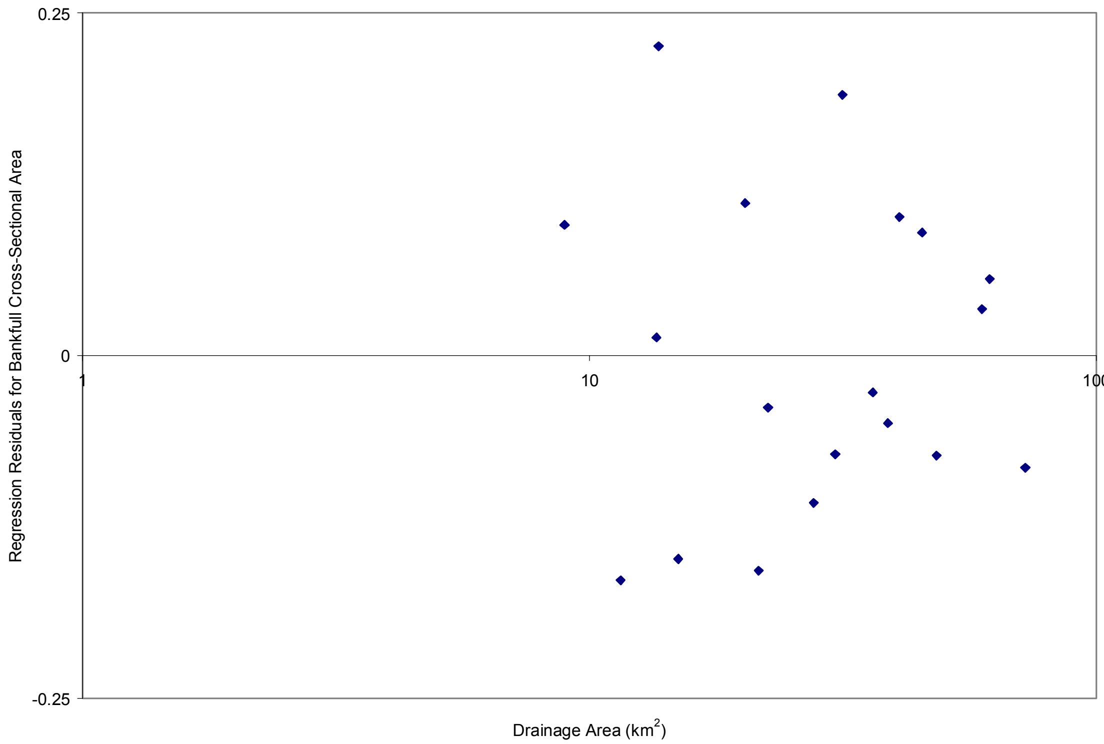

Figure 21. Regression residuals plot for bankfull cross-sectional area for regional curves for < 75 km2 non-carbonate watersheds.

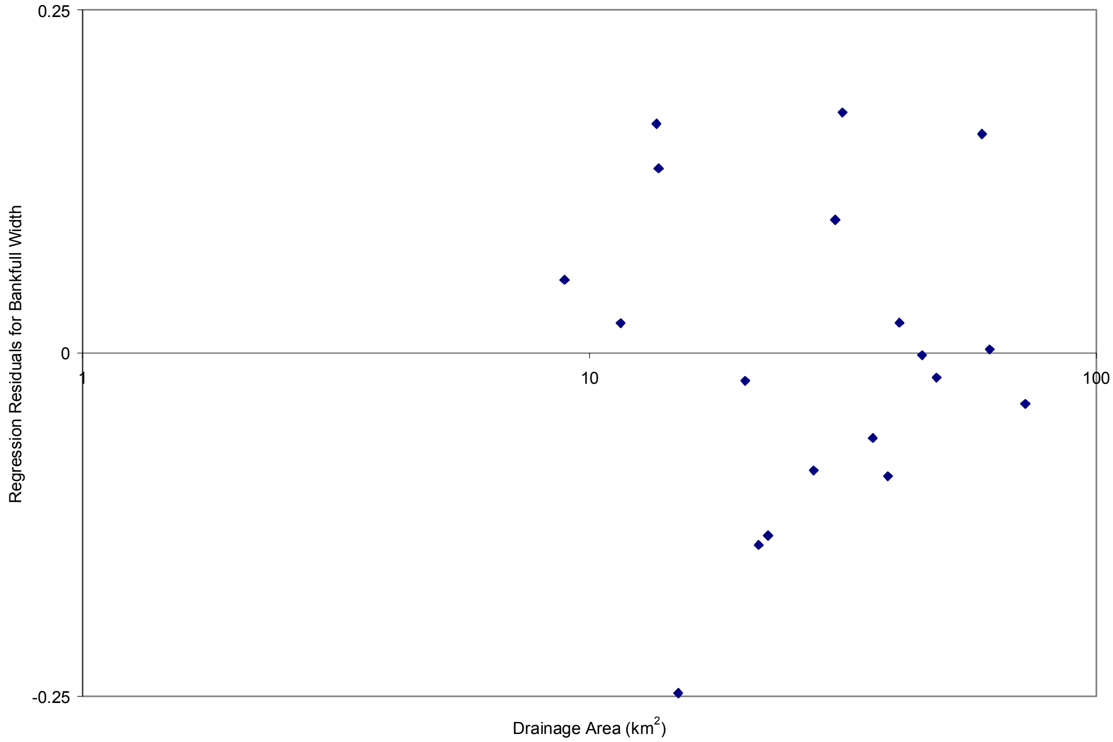

Figure 22. Regression residuals plot for bankfull width for regional curves for < 75 km2 non-carbonate watersheds.

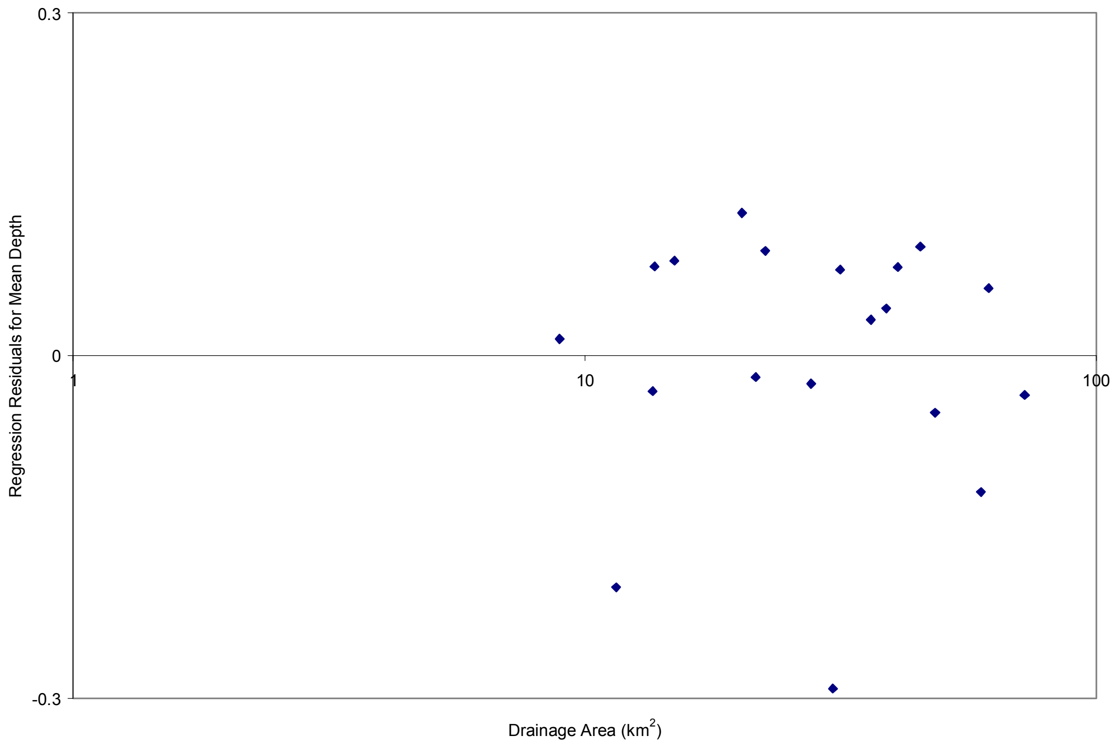

Figure 23. Regression residuals plot for bankfull mean depth for regional curves for < 75 km2 non-carbonate watersheds.

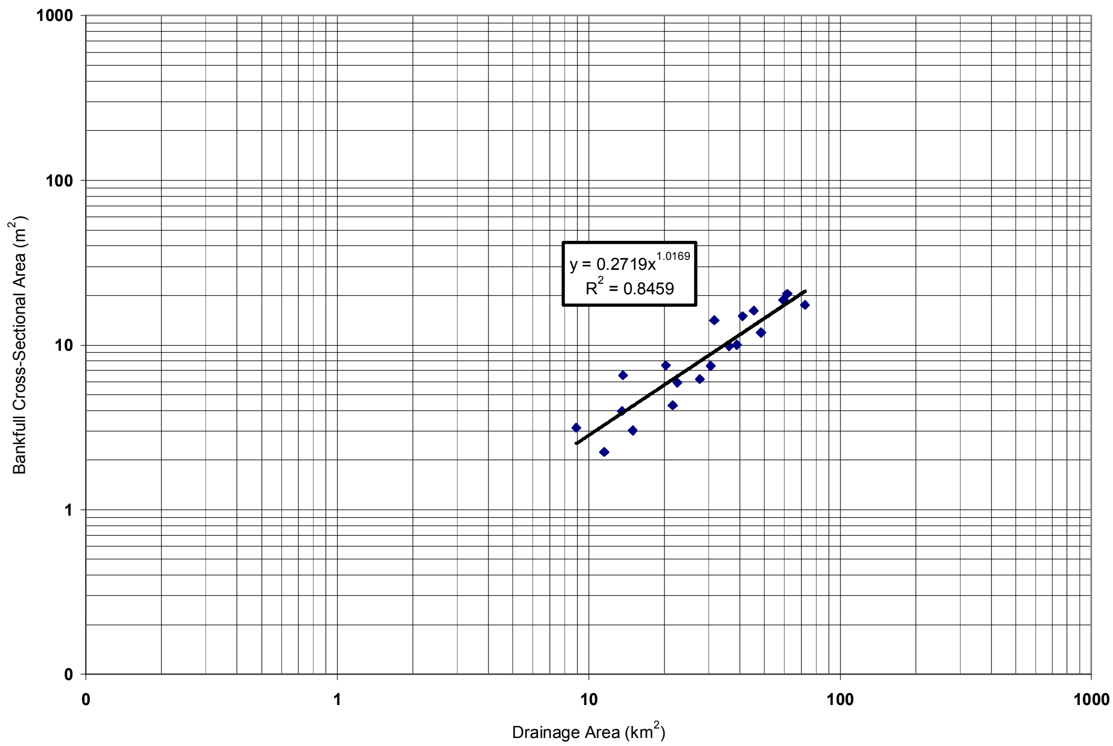

Figure 24. Regional curve for < 75 km2 non-carbonate watersheds for bankfull cross-sectional area.

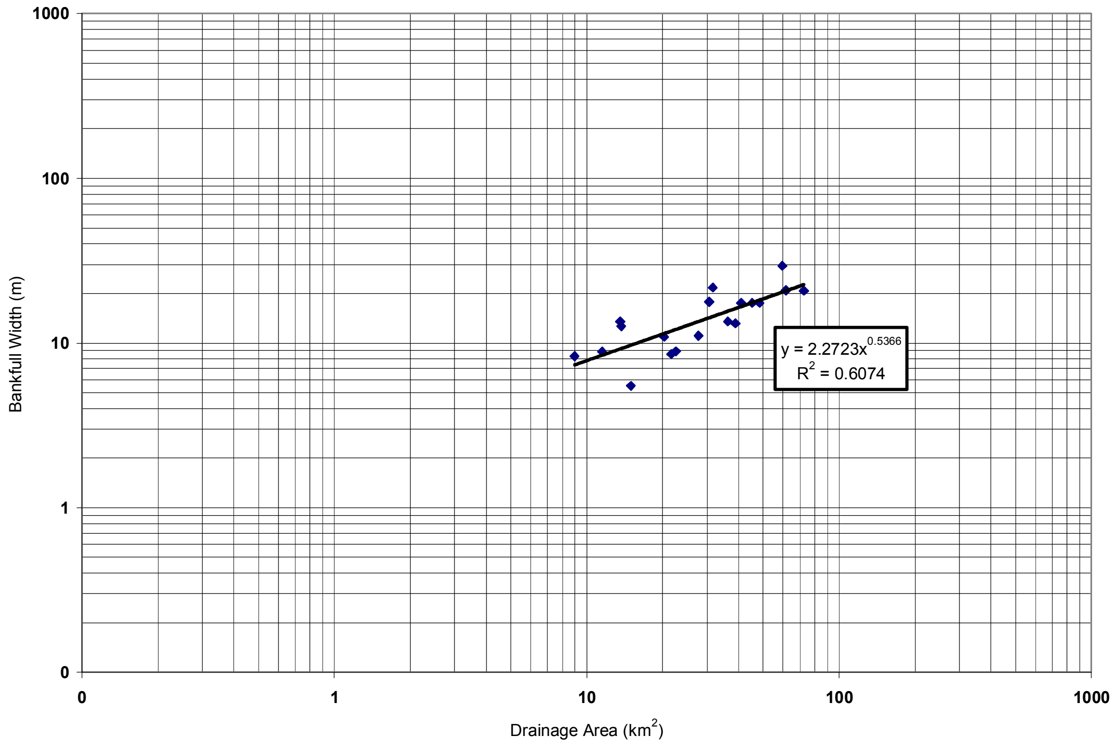

Figure 25. Regional curve for < 75 km2 non-carbonate watersheds for bankfull width.

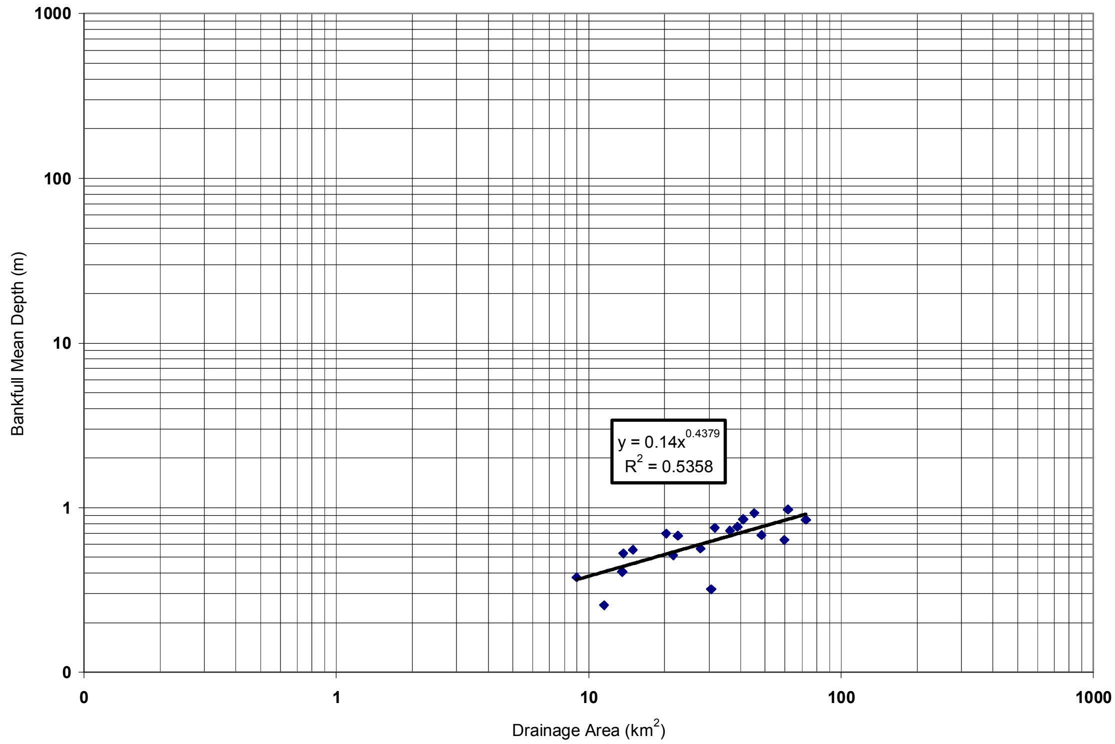

Figure 26. Regional curve for < 75 km2 non-carbonate watersheds for bankfull mean depth.

Response Variable	Equation	Slope	Y Intercept	R^2	F-statistic
Cross-Sectional Area	$CSA=0.272DA^{1.017}$	1.017	0.272	0.85	93.32
Width	$W=2.272DA^{0.537}$	0.537	2.272	0.61	26.30
Mean Depth	$D=0.140DA^{0.438}$	0.438	0.140	0.54	19.62

Table 13. Summary of quantitative attributes for regional curves for non-carbonate watersheds < 75 km2.

Comparison of Regional Curves

The p-values (Table 14) show a statistically different slope and y-intercept exists in bankfull cross-sectional area between lithologically controlled curves and the curves for < 75 km^2 non-carbonate watersheds. The p-value and coefficient for y-intercept for is 0.004 and 0.464 (Table 14) and for slope is 0.001 and -0.368 (Table 14). The lithologically controlled bankfull cross-sectional area curve thus has a greater y-intercept and lower slope than the curves for < 75 km^2 non-carbonate watersheds. The p-values (Table 14) for bankfull width are above 0.05 and, thus, the two regional curves can not be considered statistically different. The p-values (Table 14) for the bankfull mean depth regional curve indicate the y-intercept is statistically different, while slope is not. The p-value and coefficient for y-intercept for the bankfull mean depth regional curve is 0.035 and 0.262, indicating the lithologically controlled bankfull mean depth curve has a slightly larger y-intercept than the curves for < 75 km^2 non-carbonate watersheds. Comparison of regional curves reveals the hypothesis of this study must be rejected, due to a lack of significant statistical differences between the bankfull width and bankfull mean depth curves.

The lithologically controlled regional curves for all bankfull response variables have higher R^2 values, and thus greater regression validity, compared to the curves for < 75 km^2 non-carbonate watersheds (Table 14). R^2 values for the bankfull cross-sectional area curves are most comparable, at 0.88 for the lithologically controlled curves and 0.85 for the curves for < 75 km^2 non-carbonate watersheds. Comparison of the bankfull width and bankfull mean depth regional curves reveals significant differences in curve validity. The lithologically controlled curve for bankfull width explains 17% more variance (Table

Bankfull Cross-Sectional Area (m^2)						
			Intercept	Intercept	Slope	Slope
Data	**N**	R^2	p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.88	0.004	0.464	0.001	-0.368
< km^2 Curves	19	0.85	---	---	---	---
Bankfull Width (m)						
			Intercept	Intercept	Slope	Slope
Data	**N**		p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.78	0.354	0.129	0.116	-0.156
< km^2 Curves	19	0.61	---	---	---	---
Bankfull Depth (m)						
			Intercept	Intercept	Slope	Slope
Data	**N**		p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.73	0.035	0.262	0.059	-0.165
< km^2 Curves	19	0.54	---	---	---	---

Table 14. Statistical results from analysis of covariance comparison between lithologically controlled curves and regional curves for non-carbonate watersheds < 75 km2.

14) and the bankfull mean depth curve explains 19% more variance (Table 14) than the curves for < 75 km^2 non-carbonate watersheds.

Means of drainage area (Table 8) shows lithologically controlled curves are constructed from smaller watersheds versus the curves for < 75 km^2 non-carbonate watersheds. Regional curves for < 75 km^2 non-carbonate watersheds are derived of watersheds with a mean drainage area that is 14.5 km^2 (Table 8) greater than the lithologically controlled curves. Statistics for percent watershed urbanized for regional curves (Table 9) show both curves are constructed of largely rural watersheds. Statistics for percent watershed forested (Table 10) reveal significant differences in forest cover between the watersheds sampled to construct both curves. For instance, the lithologically controlled curves display on average 33.4% more forest cover than the curves for < 75 km^2 non-carbonate watersheds (Table 10).

Interpretations

Analysis shows the lithologically controlled bankfull cross-sectional area regional curve has a statistically different slope and y-intercept, and the bankfull mean depth regional curve has a statistically different y-intercept, than the curves for < 75 km^2 non-carbonate watersheds. Bedrock geology, geologic structure, physiography, riparian vegetation, and land-use conditions may cause differences in these attributes between regional curves. The lithologically controlled curves are confined to the Ridge and Valley; whereas curves for < 75 km^2 watersheds also include the Appalachian Plateaus, Central Lowland, and Piedmont Provinces.

Differences in forest cover are apparent between lithologically controlled curves and curves for < 75 km^2 non-carbonate watersheds, which can result in alterations to runoff processes that affect hydraulic geometry. Reach scale differences in riparian vegetation may exist between watersheds used to develop both regional curves. Any significant differences in vegetation may influence channel dimensions and may result in differences in the slope and y-intercept of curves.

The most important factor influencing differences in R^2 values may be the number of sites used to develop regional curves. The curves for < 75 km^2 non-carbonate watersheds are developed from 19 sites, compared to 34 sites used to construct the lithologically controlled regional curves. Accordingly, the limited number of sites used to construct the curves for < 75 km^2 non-carbonate watersheds results in lower R^2 values, and less statistical precision.

Regional Curves for Non-carbonate Watersheds in the Ridge and Valley Physiographic Province

Hydraulic Geometry Data Analysis

The characteristics of 18 non-carbonate streams (Table 15), initially investigated by Chaplin (2005), were used to develop regional curves for watersheds solely located in the Ridge and Valley Physiographic Province in Pennsylvania and selected areas of Maryland.

Kolmogorov-Smirnov normality tests (Table 16) show the test statistic for drainage area and all bankfull response variables are less than the critical value of 0.31, indicating these data are normally distributed. Plots of regression residuals for all bankfull response variables (Figures 27-29) show the variances of the residuals around the regression line are unequal, and are thus heteroscedastic. The residuals appear furthermore randomly distributed around the regression line, and are thus

USGS Gage I.D.	Physiographic Province	Drainage Area (km^2)	Bankfull XSA (m^2)	Bankfull W (m)	Bankfull MD (m)	Percent Urban	Percent Forested
1449360	v	129.24	22.11	25.15	0.84	4.7	68
1450500	v	198.65	36.33	44.50	0.83	1.2	70
1451800	v	137.27	30.84	32.31	0.95	1.1	33
1452000	v	196.32	28.89	32.31	0.82	3.7	34
1468500	v	344.47	53.51	34.44	1.55	---	---
1469500	v	111.11	13.47	16.92	0.79	2.4	77
1470756	v	411.81	62.34	47.85	1.30	1.3	40
1537000	v	83.92	10.68	14.97	0.71	---	---
1538000	v	113.44	17.65	21.12	0.84	5.8	83
1547700	v	114.22	14.86	19.45	0.78	0.2	78
1553700	v	132.87	28.06	22.71	1.22	0.5	31
1555500	v	419.58	63.27	40.54	1.56	1	67
1565000	v	424.76	50.07	35.36	1.45	1.2	63
1566000	v	554.26	113.34	60.96	1.87	0.1	70
1567500	v	38.85	10.03	13.17	0.77	0.1	49
1568000	v	536.13	87.33	61.57	1.12	0.9	68
1569340	v	13.70	6.55	12.62	0.53	1.9	34
1613050	v	27.71	6.22	11.09	0.57	0	70

Table 15. Characteristics of sites used to develop regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province. Key to symbols in table: [XSA] Cross-Sectional Area, [W] Width, [MD] Mean Depth, [v] Ridge and Valley, [---] missing data.

Sample Description	Kolmogorov-Smirnov Test Statistic
Drainage Area	0.238
Cross-Sectional Area	0.185
Width	0.131
Depth	0.215

Table 16. Kolmogorov-Smirnov normality test statistics for regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province. A sample size (n) = 18 yields a critical value of 0.31.

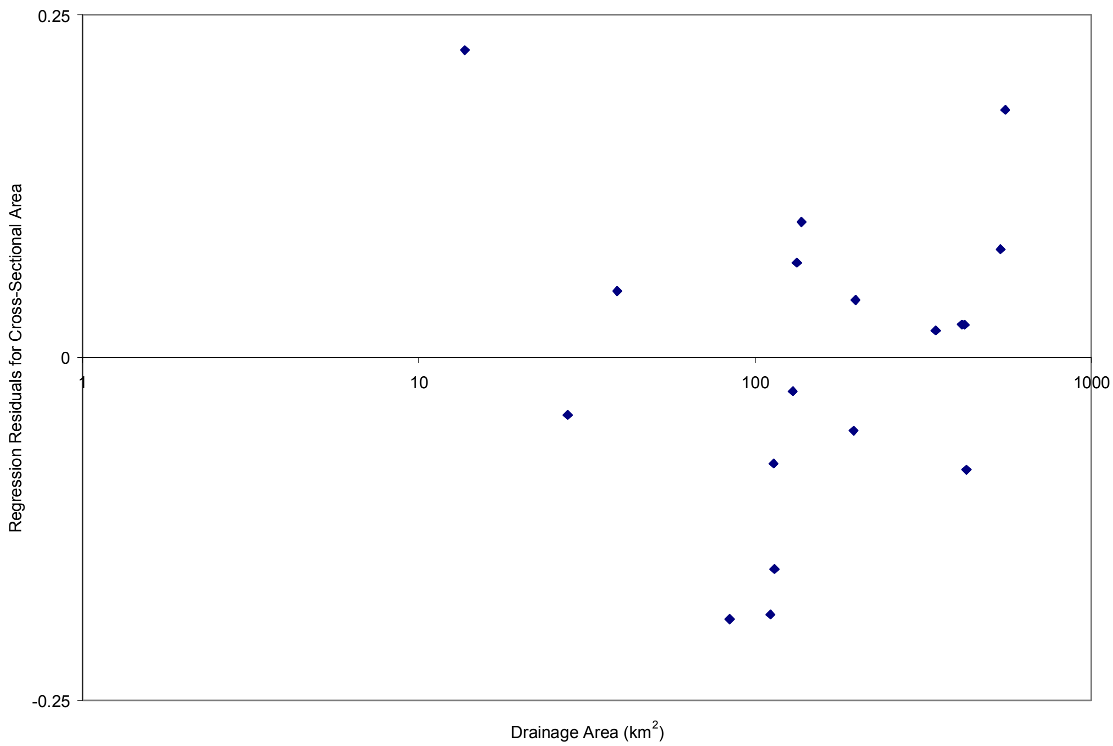

Figure 27. Regression residuals plot for bankfull cross-sectional area for regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province.

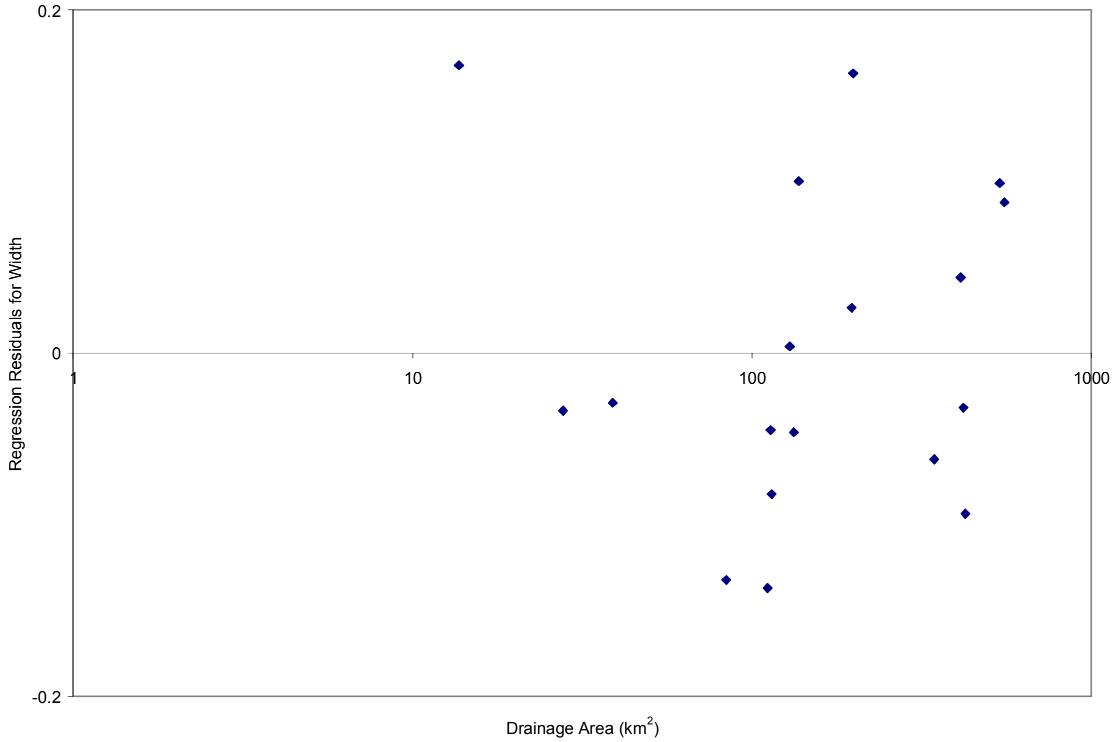

Figure 28. Regression residuals plot for bankfull width for regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province.

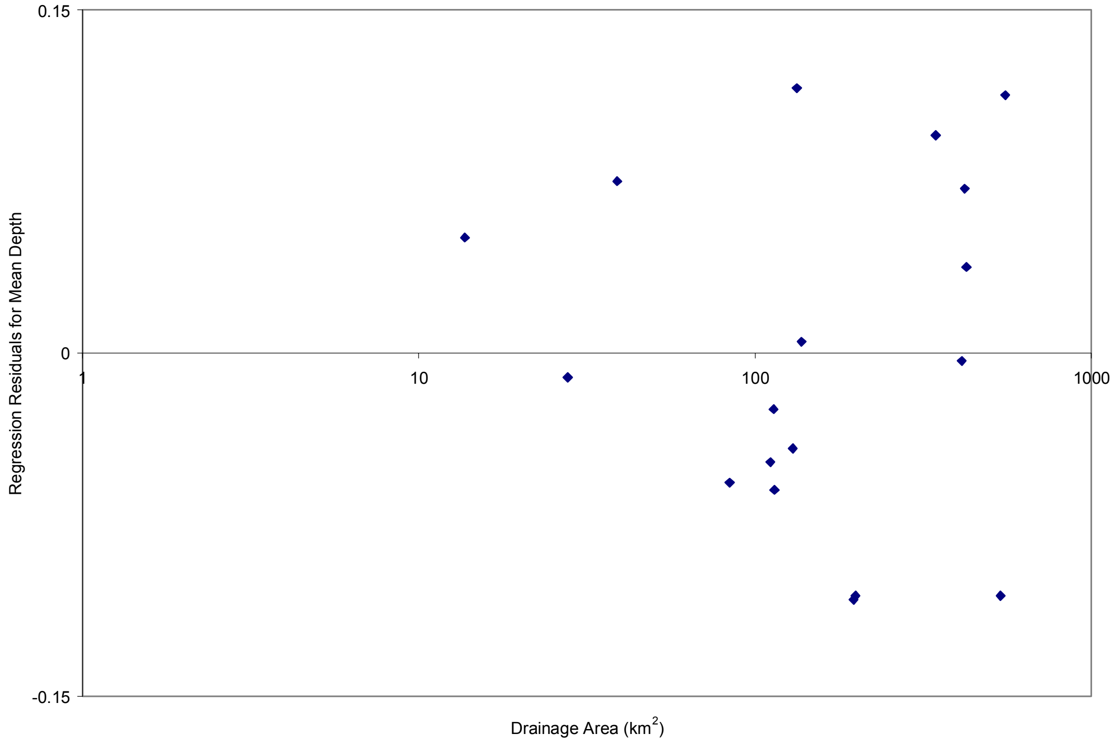

Figure 29. Regression residuals plot for bankfull mean depth for regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province.

non-autocorrelated. A linear and causal relationship between drainage area and all of the bankfull response variables can be assumed.

Regional Curve Development

R^2 values for bankfull cross-sectional area (Figure 30, bankfull width (Figure 31), and bankfull mean depth (Figure 32) regional curves are 0.908, 0.841, and 0.768, respectively (Table 17). F-statistic values are also highest for bankfull cross-sectional area, followed by bankfull width and bankfull mean depth (Table 17). Therefore, the bankfull cross-sectional area regional curve displays the least variance and best fit, followed by bankfull width and, lastly, bankfull mean depth.

Comparison of Regional Curves

The p-values (Table 18) for the bankfull cross-sectional area regional curve indicate a statistically different slope exists between lithologically controlled curves and curves for non-carbonate Ridge and Valley watersheds. The p-value and slope coefficient for the bankfull cross-sectional area curve is 0.048 and -0.150 (Table 18). Accordingly, the lithologically controlled bankfull cross-sectional area regional curve has a slightly lower slope than the curves for non-carbonate watersheds solely located in the Ridge and Valley. The p-values for slope and y-intercept for bankfull width and bankfull mean depth curves are all above 0.05, so the curves can not be considered statistically different, and the research hypothesis again must be rejected due to a lack of statistical differences between the bankfull width and bankfull mean depth regional curves.

The regional curves for non-carbonate Ridge and Valley watersheds for all bankfull response variables have moderately larger R^2 values than the lithologically

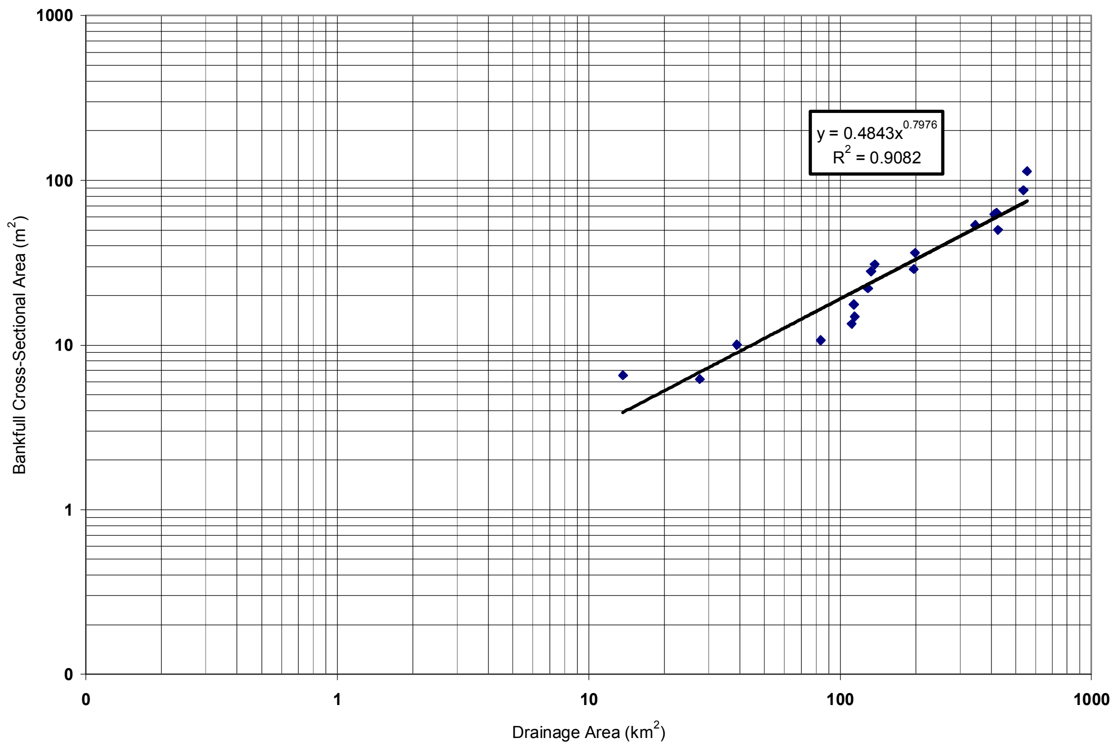

Figure 30. Regional curve for non-carbonate watersheds for the Ridge and Valley Physiographic Province for bankfull cross-sectional area.

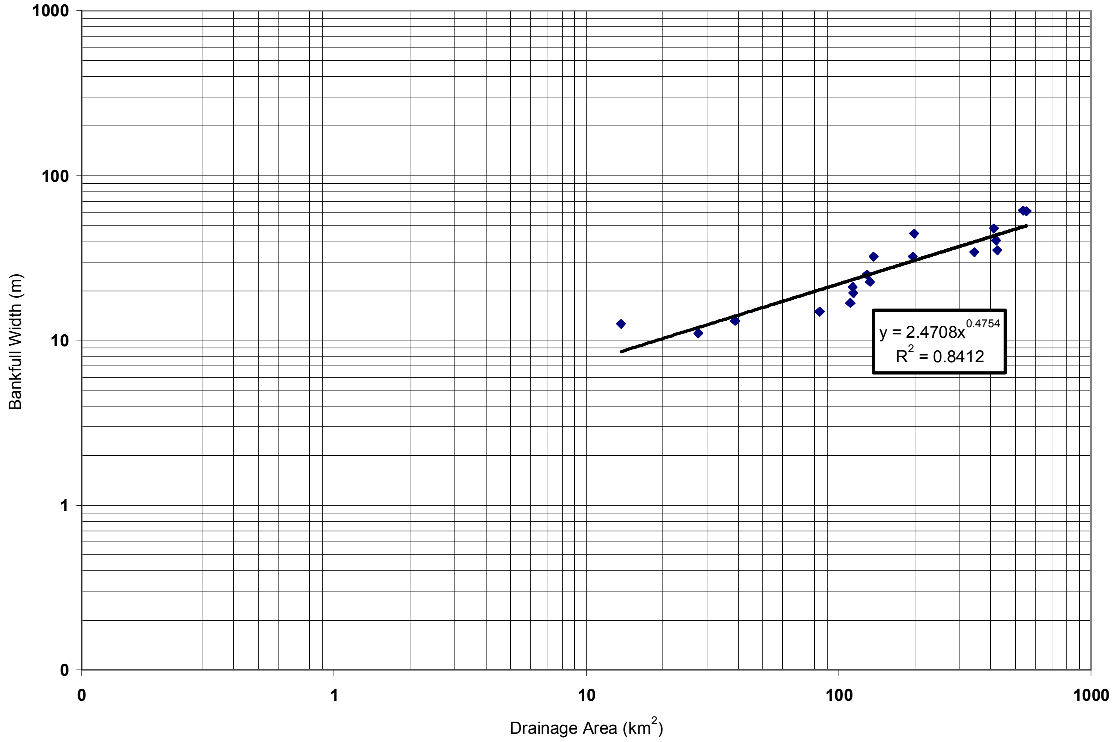

Figure 31. Regional curve for non-carbonate watersheds for the Ridge and Valley Physiographic Province for bankfull width.

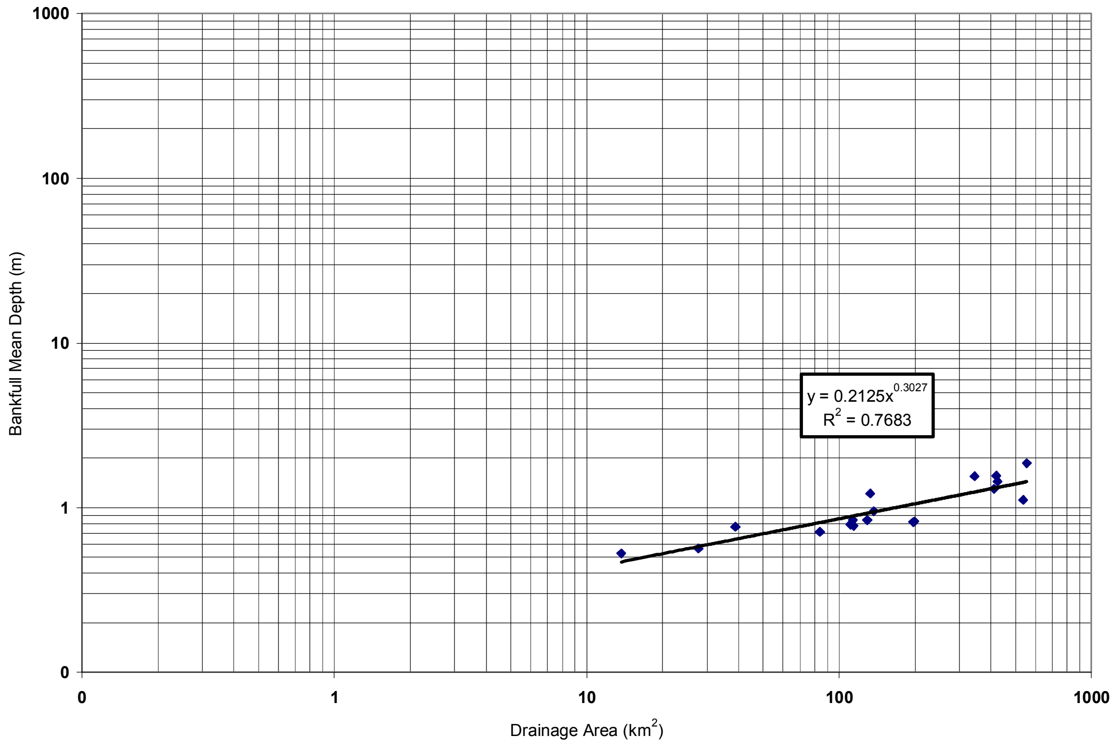

Figure 32. Regional curve for non-carbonate watersheds for the Ridge and Valley Physiographic Province for bankfull mean depth.

Response Variable	Equation	Slope	Y Intercept	R^2	F-statistic
Cross-Sectional Area	$CSA=0.484DA^{0.798}$	0.798	0.484	0.91	158.21
Width	$W=2.471DA^{0.475}$	0.475	2.471	0.84	84.74
Mean Depth	$D=0.213DA^{0.303}$	0.303	0.213	0.77	53.06

Table 17. Summary of quantitative attributes for regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province.

Bankfull Cross-Sectional Area (m^2)						
			Intercept	Intercept	Slope	Slope
Data	**N**	R^2	p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.88	0.133	0.213	0.048	-0.150
R & V Curves	18	0.91	---	---	---	---
Bankfull Width (m)						
			Intercept	Intercept	Slope	Slope
Data	**N**		p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.78	0.43	0.093	0.129	-0.095
R & V Curves	18	0.84	---	---	---	---
Bankfull Depth (m)						
			Intercept	Intercept	Slope	Slope
Data	**N**		p-value	Coefficient	p-value	Coefficient
Controlled Curves	34	0.73	0.391	0.081	0.547	-0.030
R & V Curves	18	0.77	---	---	---	---

Table 18. Statistical results from analysis of covariance comparison between lithologically controlled curves and regional curves for non-carbonate watersheds for the Ridge and Valley Physiographic Province.

controlled curves. Bankfull cross-sectional area regional curves are most comparable, with R^2 values of 0.91 for curves for Ridge and Valley watersheds and 0.88 for the lithologically controlled curves. R^2 values for the bankfull width relations are 0.84 for Ridge and Valley watershed curves and 0.78 for lithologically controlled curves. Lastly, bankfull mean depth R^2 values are 0.77 for the Ridge and Valley curves and 0.73 for the lithologically controlled curves.

Means of drainage area (Table 8) show lithologically controlled curves are derived from a mean drainage area of 18.2 km^2, 203.4 km^2 less than the mean drainage area for the curves for non-carbonate Ridge and Valley watersheds. Standard deviation values (Table 8) show the curves for Ridge and Valley watersheds are derived from a much broader range of drainage areas than lithologically controlled curves.

Statistics for percent watershed urbanized (Table 9) shows both regional curves are derived from largely rural watersheds. Statistics shows the mean percent watershed forested for the lithologically controlled curves is 97.7%, 39.3% more than the mean for the curves for non-carbonate Ridge and Valley watersheds (Table 10).

Interpretations

The lithologically controlled regional curve for bankfull cross-sectional area has a statistically different slope than the curves for non-carbonate Ridge and Valley watersheds. Bedrock geology, geomorphic history, channel gradient, watershed size, riparian vegetation, and land-use may yield differences between these curves. Bedrock geology and geomorphic history vary within the Ridge and Valley Physiographic Province (Sevon 2000) and, therefore, differ between sites used to develop both regional curves.

Channel gradients may be greater at sites included in lithologically controlled regional curves, possibly resulting in different channel forming discharges for riffles within a reach and variable channel dimensions. Mean drainage area and degree of unforested land cover for sites used to construct lithologically controlled regional curves are smaller than those used to develop curves for non-carbonate Ridge and Valley watersheds, so these watersheds almost certainly have a flashier hydrologic regime. Moreover, riparian vegetation type and density may differ between the sites used to develop both curves.

The factors that may influence differences in R^2 values include the number of sites used to construct curves, channel gradient, and watershed size. The curves for non-carbonate Ridge and Valley watersheds solely were developed from 18 sites, compared to 34 used to construct lithologically controlled curves. Therefore, the regional curves developed with fewer sites have greater regression validity, or higher R^2 values. This result may be in part influenced by not having a representative sample of the statistical population, yielding few outliers and higher R^2 values.

Channel gradients are higher at the sites used in lithologically controlled curves, and are associated with poorly developed and difficult to identify floodplains, resulting in smaller R^2 values. Survey measurement of the channel cross-section of small streams may also result in large relative errors and yield inaccurate values for bankfull response variables. Thus, as previously stated, due to measurement error, curves developed from smaller streams may result in more variance.

Combined Regional Curves for Non-Carbonate Watersheds

Hydraulic Geometry Data Analysis

The characteristics of the 34 streams (Table 4) used in the development of lithologically controlled curves and the 55 streams (Table 1) used in the development of Chaplin's (2005) regional curves were used to develop of a combined regional curve for all non-carbonate watersheds.

Kolmogorov-Smirnov normality tests (Table 19) shows all of the bankfull response variables have test statistics less than the critical value of 0.21, and are normally distributed; however, the drainage area data, has a test statistic value of 0.218, very slightly above the critical value, and is non-normally distributed. Logarithmic transformation of the drainage area data to create a normal distribution would make comparison of regional curves impossible, so such transformation is not warranted.

Plots of regression residuals for all bankfull response variables (Figures 33-35) show unequal variances of the residuals about the regression line, so the data are heteroscedastic. Regression residuals are randomly distributed around each regression line, so non-autocorrelation of the variables is assumed. A linear and causal relationship between drainage area and all of the bankfull response variables can be assumed.

Regional Curve Development

The bankfull cross-sectional area regional curve (Figure 36) has the largest R^2 value, 0.95 (Table 20). R^2 values for bankfull width (Figure 37) and bankfull mean depth (Figure 38) regional curves are 0.90 and 0.81, respectively (Table 20). F-statistic values are significantly high for all combined regional curves (Table 20), indicating a large

Sample Description	Kolmogorov-Smirnov Test Statistic
Drainage Area	0.218
Cross-Sectional Area	0.194
Width	0.131
Depth	0.134

Table 19. Kolmogorov-Smirnov normality test statistics for combined regional curves for non-carbonate watersheds. A sample size (n) = 89 yields a critical value of 0.21.

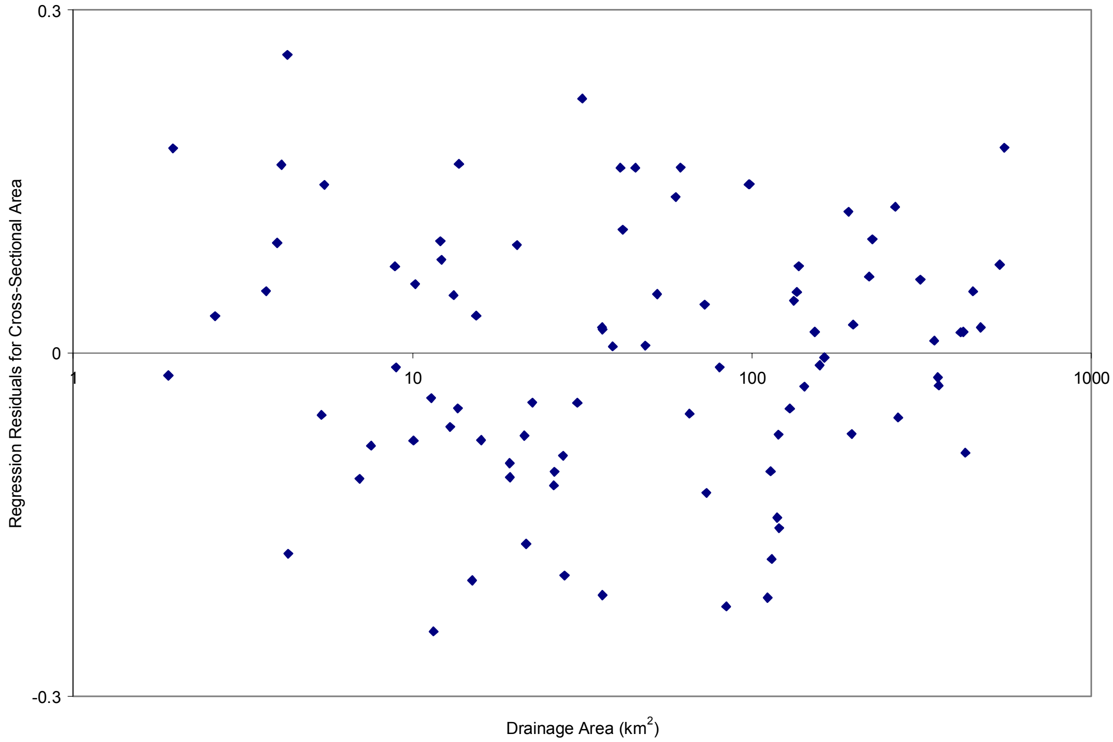

Figure 33. Regression residuals plot for bankfull cross-sectional area for combined regional curves for non-carbonate watersheds.

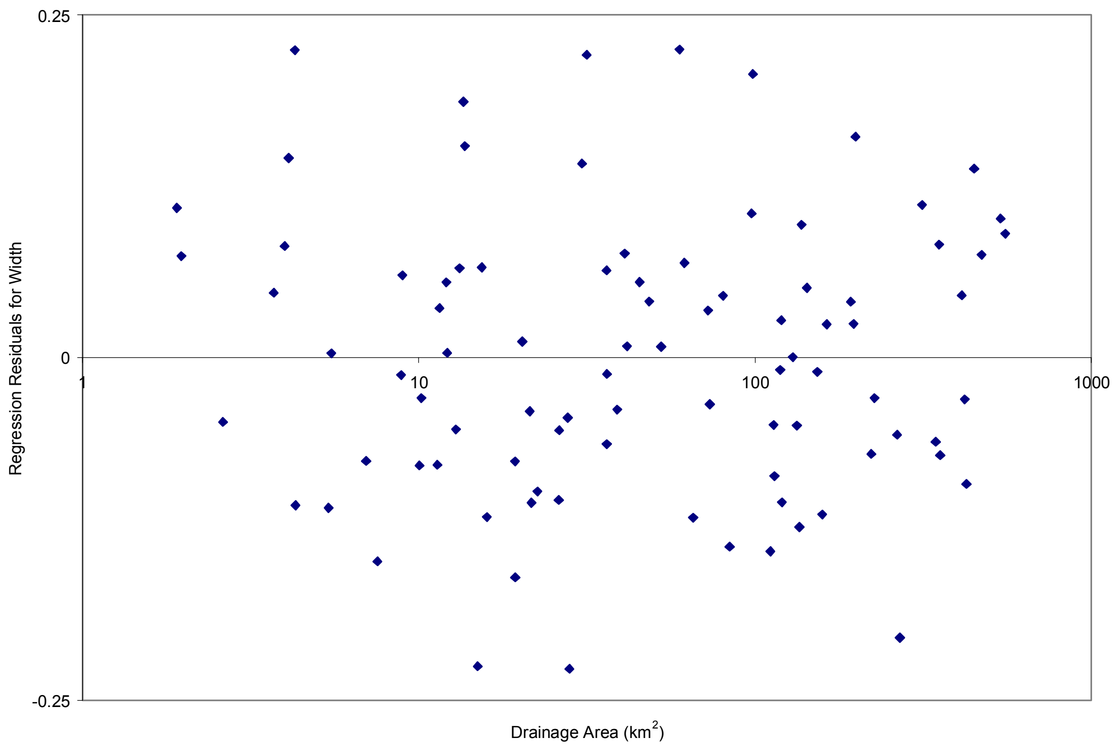

Figure 34. Regression residuals plot for bankfull width for combined regional curves for non-carbonate watersheds.

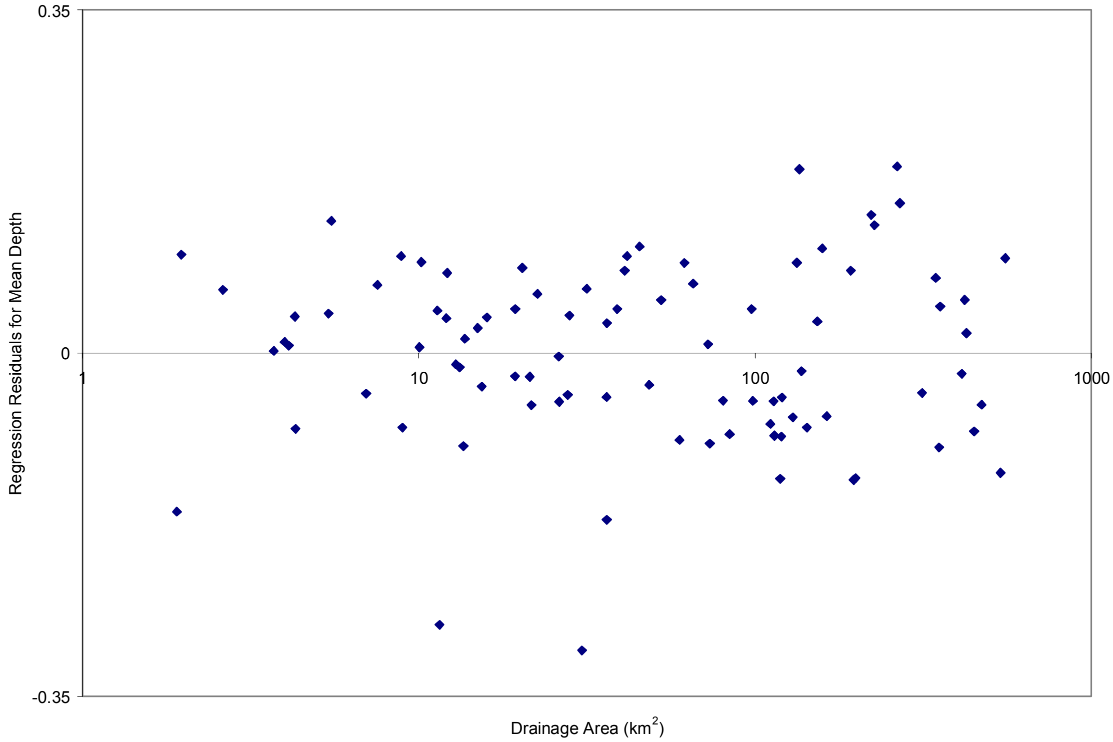

Figure 35. Regression residuals plot for bankfull mean depth for combined regional curves for non-carbonate watersheds.

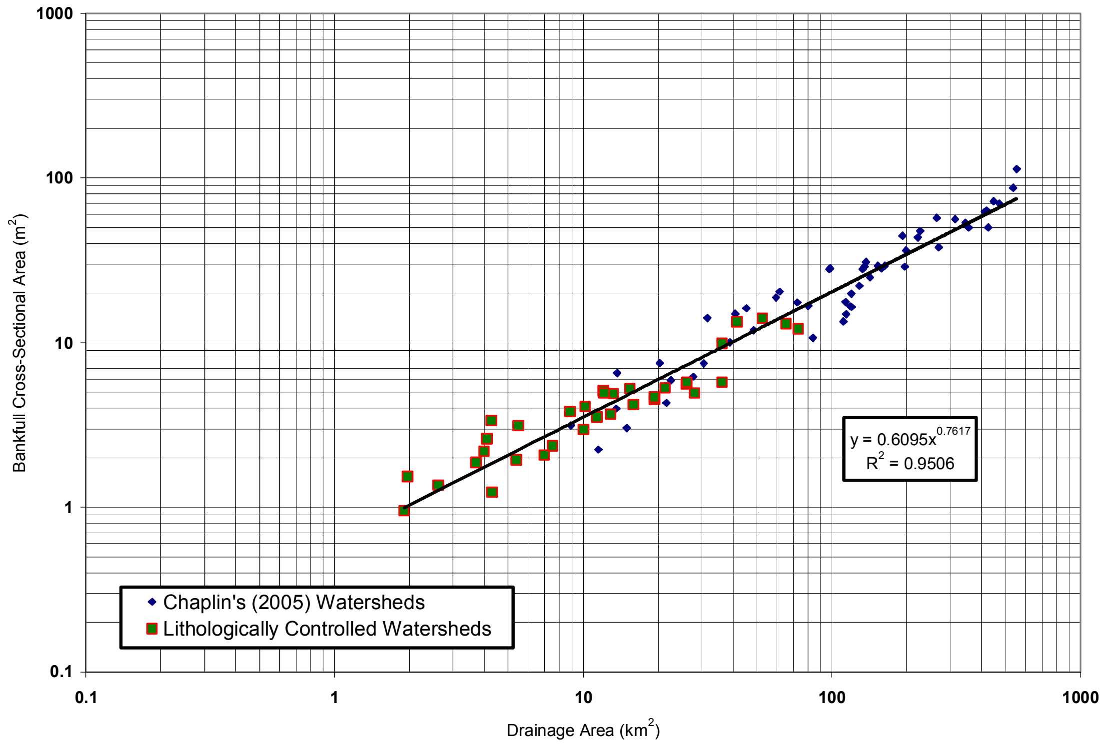

Figure 36. Combined regional curve for non-carbonate watersheds for bankfull cross-sectional area.

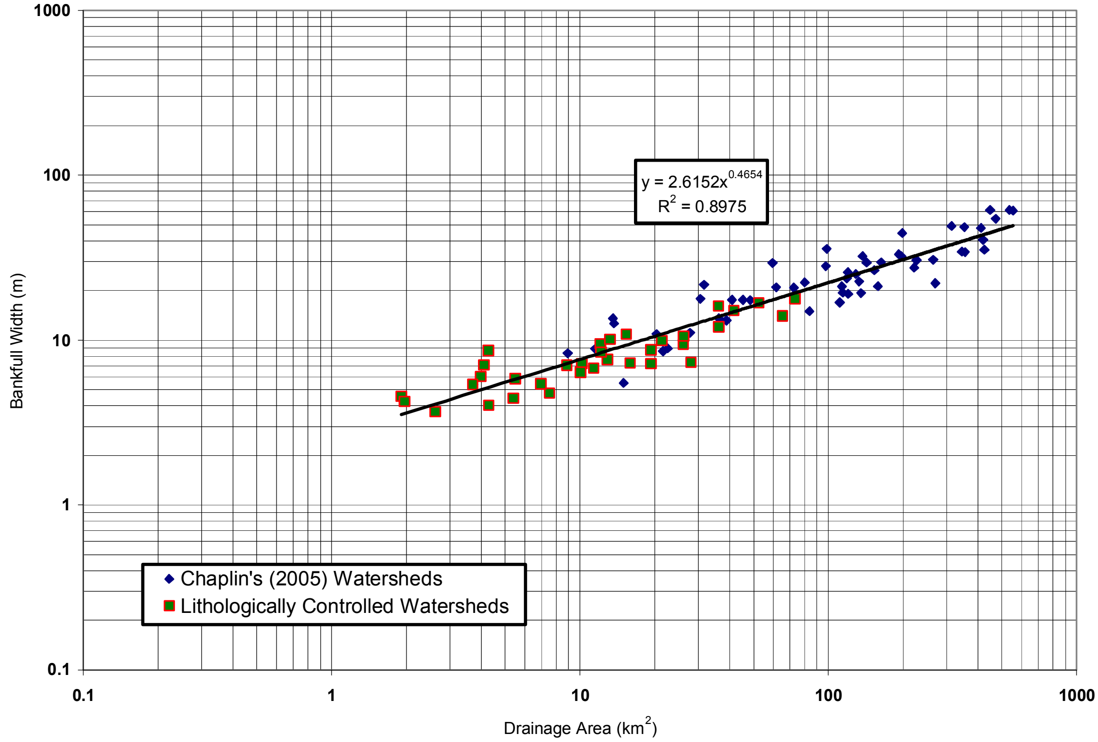

Figure 37. Combined regional curve for non-carbonate watersheds for bankfull width.

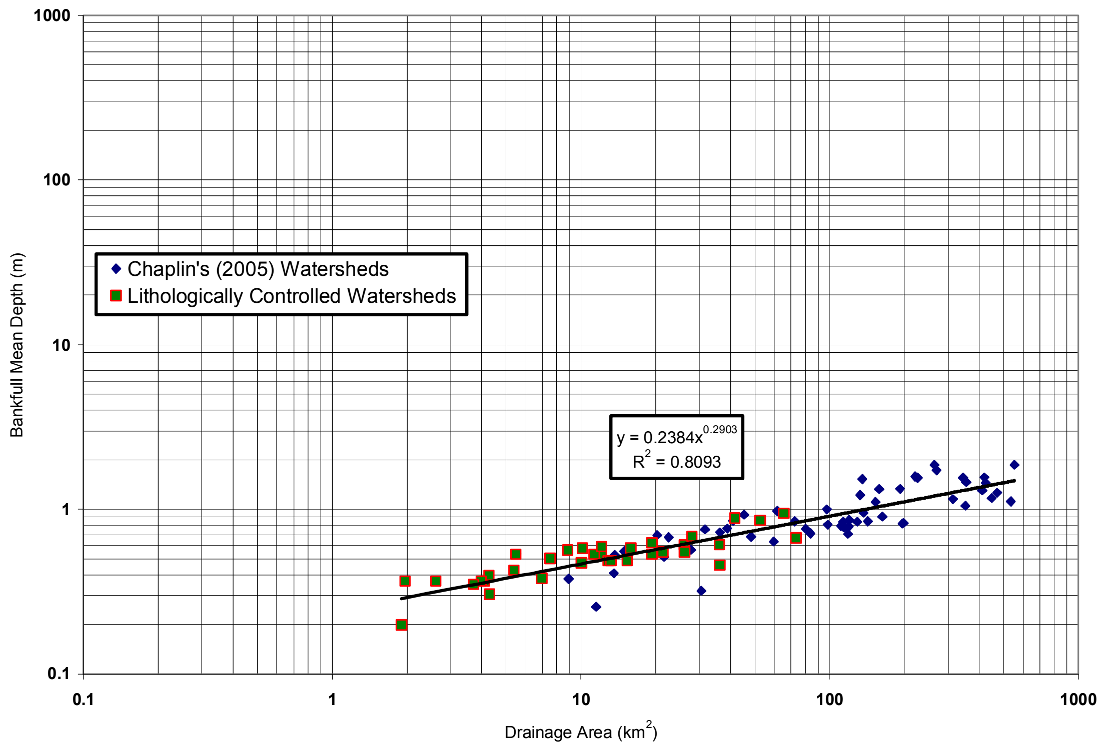

Figure 38. Combined regional curve for non-carbonate watersheds for bankfull mean depth.

Response Variable	Equation	Slope	Y Intercept	R^2	F-statistic
Cross-Sectional Area	$CSA=0.610DA^{0.762}$	0.762	0.610	0.95	1675.32
Width	$W=2.615DA^{0.465}$	0.465	2.615	0.90	762.17
Mean Depth	$D=0.238DA^{0.290}$	0.290	0.238	0.81	369.30

Table 20. Summary of quantitative attributes for combined regional curves for non-carbonate watersheds.

sample size produces better regression fit. Overall, the bankfull cross-sectional area regional curve has the least variance and best regression validity, followed by the bankfull width and lastly bankfull mean depth curves.

Comparison of Regional Curves

R^2 values for the combined regional curves for non-carbonate watersheds for all bankfull response variables (Table 20) are significantly larger than values for the lithologically controlled curves (Table 6). The R^2 values for the bankfull cross-sectional area regional curves are most alike, at 0.95 for the combined curves and 0.88 for the lithologically controlled curves. The R^2 value for the combined bankfull width curve is 0.90, explaining 12% more variance than the lithologically controlled curve. Lastly, the 0.81 R^2 value for the combined bankfull mean depth curve explains 8% more variance than the lithologically controlled curve.

Interpretations

The number of sites used to construct regional curves, channel gradient, and watershed size may influence the high R^2 values of the combined regional curves. The combined regional curves are developed with 89 sites, compared to 34 used to construct the lithologically controlled regional curves. Thus, the combined curves constructed with a significantly larger sample size produce less variance and greater statistical precision.

The mean drainage area for watersheds used to construct the combined regional curves was 108.4 km^2 (Table 8), compared to 18.2 km^2 (Table 8) for the lithologically controlled curves. In addition, small mountain streams have high gradients and greater reach scale variability between adjacent riffles, producing poorly developed floodplains and significant local differences in dominant discharge and as a result, channel form. Difficulty in accurately surveying smaller streams likely results in more error and greater variance from the true value of channel geometry. All of these factors combined are suspected to cause the lithologically controlled curves to have more variance than the combined curves.

Analysis of Channel Sedimentology

Results of Channel Bedload Sediment Investigation

The riffle sedimentology data and cumulative frequency distributions for each pebble-count are given in Appendix 2. A plot relating the texture of the D_{50} and D_{84} for each study reach is included in Appendix 3. Each plot shows variation in bedload texture appear random with increasing watershed area; no downstream fining or coarsening trend can be discerned in the lithologically controlled setting for either D_{50} or D_{84}. The behavior of the D_{50} and D_{84} on all plots is similar, where coarsening or fining occurs in the D_{50}, the same occurs in the D_{84}. A best-fit line relating D_{50} and D_{84} to drainage area for all field-investigated reaches (Figure 39) yielded R^2 values for the D_{50} and D_{84} of only 0.0081 and 0.0034, respectively, indicating no significant trend exists in downstream changes in the texture of bedload sediments.

Interpretations

Analysis of channel sedimentology results reveals the texture of bedload sediments is highly variable as drainage area increases. Although not quantified in the field, observation of the study streams along the longitudinal profile revealed significant changes in channel gradient between adjacent riffles. Higher channel gradients result in

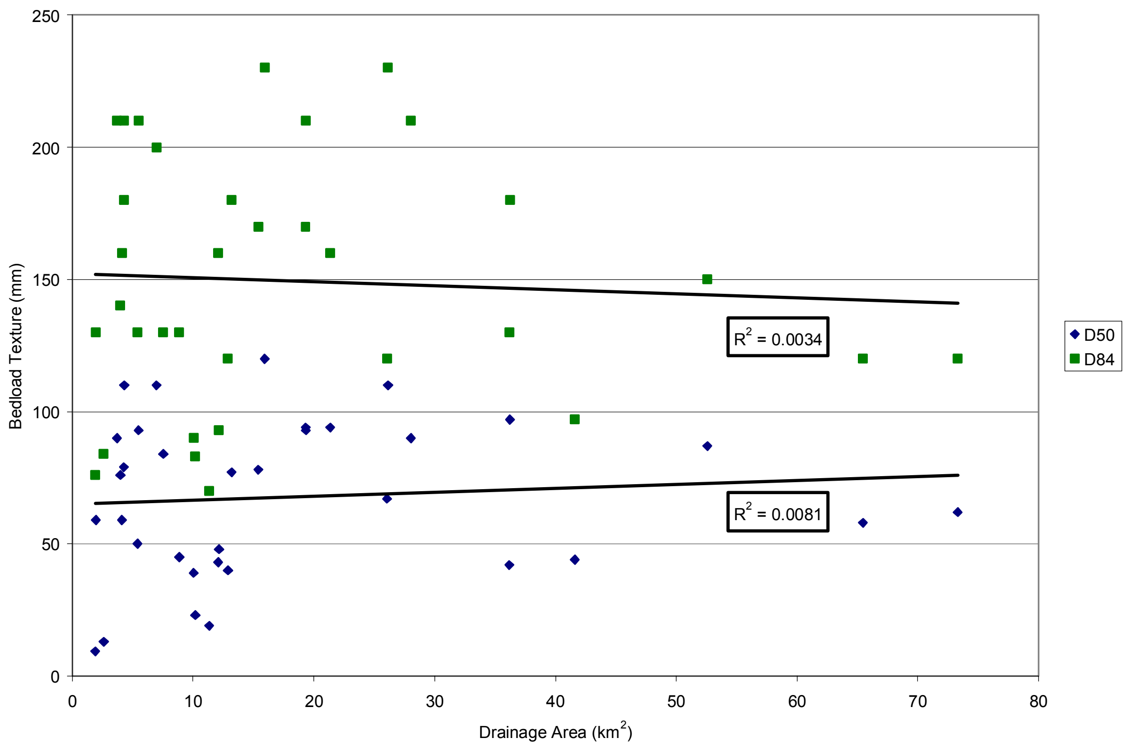

Figure 39. Texture of D50 and D84 of channel bedload sediments versus drainage area for all lithologically controlled watersheds.

higher flow velocity and stream power than lower channel gradients. Bedload transport is related to the transporting capacity of a given flow, and therefore is related to channel gradient through velocity (Knighton 1998). Thus, local sorting of bedload in riffle sections may give rise to variability of bedload textures as watershed size increases. In validation of the influence of channel gradient on bedload textures, Jarrett (1984) found a positive correlation between the D_{84} and channel slope for mountain rivers in the Rocky Mountains of Colorado.

The texture of bedload sediments generally decrease in size as the distance downstream increases (Knighton 1998), in contrast to this study's findings. Mechanical disintegration of bedload sediments through abrasion and a decrease in transport capacity as distance downstream increases results in downstream fining (Leopold 1994). However, alluvial input from tributaries and mass movement input from adjacent hill slopes can re-supply stream channels and result in more complex bedload relationships. In the study area of the lithologically controlled watersheds, tributary and hill-slope input may be important sources of bedload to the master streams. Most of the lithologically controlled streams display a trellis drainage pattern, with numerous small, high gradient low-order tributaries that intermittently re-supply the master channel with coarse sediments. Therefore, tributary input might contribute to the apparently random relationship between bedload textures and drainage area.

Hill slope input to stream channels may result from mass movement of the extensive surficial deposits that blanket the slopes that transition from valleys bottoms to ridge tops in the study watersheds. Movement of these surficial deposits may occur when hill slopes are undercut by meandering streams or excessive precipitation results in slope instability. Other factors may influence mass wasting in the study watersheds, including historical deforestation and road construction. When colluvial sediments reach adjacent streams, channels likely become overloaded with sediment. Accordingly, the input of coarse sediment from adjacent hill slopes may intermittently resupply the study streams, resulting in the random relationship between bedload texture and drainage area.

Conclusions

The variables that influence natural channel dimensions, bedrock geology, geologic structure, channel gradient, watershed size, riparian vegetation, and land use, vary significantly across and within physiographic provinces and at the reach scale. Previous regional curve investigations in the Appalachian Highlands (Chaplin 2005; Keaton et al. 2005) have considered physiography and land use, specifically urbanization, and also explored the impact of carbonate geology on drainage area-discharge relationships.

In this study, regional curves are developed for lithologically similar watersheds within the Ridge and Valley Physiographic Province. Documented statistical variations in slope and y-intercept between the lithologically controlled curves and curves for varying physiography and watershed size are summarized in Table 21. As a result, future investigators should make an effort to constrain additional variables that influence channel dimensions within physiographic provinces, in an attempt to increase the statistical precision of regional curve equations.

Watershed size and channel gradient may be influential in causing differences in slope and y-intercept between the lithologically controlled regional curves and the three distinct regional curves derived from watersheds of varying size and physiography.

Regional Curve	**Lithologically Controlled Watersheds**					
	Bankfull Cross-Sectional Area		**Bankfull Width**		**Bankfull Mean Depth**	
Curve Attribute	*Slope*	*Intercept*	*Slope*	*Intercept*	*Slope*	*Intercept*
Chaplin's (2005) Curves	Lower	Higher	----	----	----	----
Curves for < 75 km^2 Watersheds (Chaplin's Data)	Lower	Higher	----	----	----	Higher
Curves for Ridge and Valley (Chaplin's Data)	Lower	----	----	----	----	----

Table 21. Summary of key results from slope and y-intercept comparisons between regional curves. Key to symbols in table: [Lower] A lower slope/intercept exists for lithologically controlled regional curves, [Higher] A higher slope/intercept exists for lithologically controlled regional curves, [----] No statistical difference exists between regional curves.

These factors, furthermore, may be important in producing variability in R^2 values, or explained variance. Specifically, regional curves derived from relatively small watersheds in mountain settings are shown to produce lower R^2 values than curves developed from larger watersheds from lowland settings. As a result, future investigations could group watersheds according to drainage area and streams according to channel gradient, and develop unique relationships for each. By grouping watersheds into classes according to size and gradient, it may be possible to separate mountain rivers with a flashier hydrology from lowland rivers. Comparison of regional curve slope and y-intercept values and of R^2 values from regression analysis between the groups may reveal if this strategy is worthwhile in increasing explained variance or producing statistically unique regional curve equations.

The development of regional curves has been historically limited to stream flow gauge sites with good flood frequency records, and so the overwhelming majority of watersheds are ignored. This historic limitation is related to the development of regional curves relating drainage area to bankfull discharge. However, in stream restoration, the proper size of design channels on ungauged streams can be estimated with the assistance of a bankfull cross-sectional area, bankfull width, and bankfull mean depth regional curve (Harmon et al. 1999). If channel gradient is measured in the field at an ungauged stream reach, bankfull discharge can be estimated using the slope-conveyance or critical depth methods. Jarrett and England (2002) have shown that using either of these methods results in discharge values within twenty-five percent of actual values. Therefore, future development of regional curves should include ungauged watersheds.

The number of sites used to develop regional curves for physiographic provinces in Pennsylvania almost always is correlated with variance, if all other independent variables remain constant. As sample size increases, the precision of curve equations increases, and variance decreases, assuming a representative sample has been collected. In this study, the combined regional curves for non-carbonate watersheds are developed from 89 sites, resulting in high explained variance for all bankfull variables. Furthermore, these curves are derived from gauged and ungauged watersheds, allowing such a large sample size in curve development. Thus, the inclusion of ungauged sites in regional curves will allow larger data sets and may yield curve equations with greater statistical precision and less variance.

A suggested methodology for future curve investigations would involve first, determining which variables controlling hydraulic geometry are to be constrained. A large number of gauged and ungauged streams should be then sampled, resulting in a data set that may potentially be sub-sampled into groups based on drainage area and channel gradient differences. To ascertain if grouping of the sampled streams is warranted, cluster analysis may be utilized. Results from cluster analysis may define thresholds to assemble the sampled streams into distinctive groups, based on similarities in drainage area and channel gradient. If clustering of data is apparent, unique regional hydraulic geometry curves should be developed for the watershed groups and the slopes and y-intercepts of the curves should be compared using analysis of covariance, to assess if the curve attributes are statistically different.

Limitations and Constraints on the Applications of Lithologically Controlled Regional Curves

The limitations associated with regional curve development relate to the fulfillment of the requirements of regression analysis. These limitations relate to a lack normally distributed and heteroscedastic residuals. Constraints on the application of existing regional curves stem from the attributes of the watersheds used to develop the relations. It is important to note that regional curves should not be the sole means to estimate bankfull channel dimensions. Additional methods, such as field-evidenced bankfull stage identification and flood-flow records, should be coupled with use of the regional curves. The lithologically controlled regional curves for non-carbonate watersheds should be used only when the following requirements are met:

- The criteria used in the selection of watersheds for regional curves must be fulfilled.
- Use of regional curves is limited to the range of watersheds sampled in the development of regional curves, between 1.91 to 73.3 km^2.
- Use of regional curves from this study is limited to watersheds that did not experience glacial erosion or deposition during the Pleistocene Epoch.
- Percent urban land use must be minimal, less than 1% per watershed area.
- Percent forest cover must be the dominant land cover, with at least 85% per watershed area.

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Appendix 1. Characteristics of the measured riffles and channel survey data for lithologically controlled watersheds.

The data collected while surveying the channel cross-section of all of the measured riffles is available in Appendix 1. The appendix also includes the coordinates of the measured riffles in the Universal Transverse Mercator system using the North American Datum of 1927, a description of the reach location, graphs of the surveyed channel cross-sections, the drainage area of the riffle watersheds, the field evidenced bankfull stage indicator, and riffle scale calculations for all of the bankfull response variables. The highest elevation measured at each riffle was later adjusted to a base level of 100 feet, for consistency in the channel cross-section graphs. A uniform scale is used on all channel cross-section graphs, to allow for visual comparison between the study watersheds. The horizontal blue line in the channel cross-section graphs indicates the elevation of the bankfull stage. The study streams were initially surveyed and the bankfull response variables were calculated in English units (feet). The bankfull stage elevation is noted by bolder text and an asterisk (*) after the value. Conversion of the bankfull response variables to metric units was carried out after the reach average was calculated (Table 4).

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 Time of Survey: 9:35 am

Reach #: 1-A Drainage Area: 0.74 sq. miles

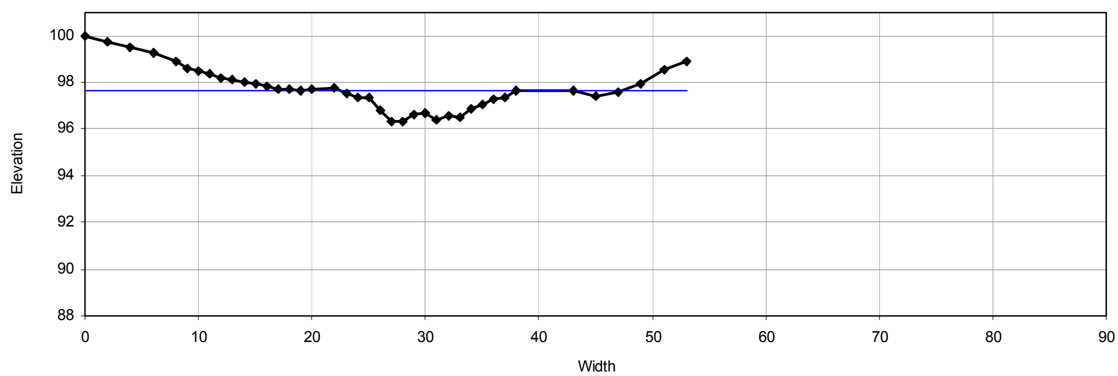
UTM Coordinate Location: Zone 18, 4425801 m N, 0247456 m E

Location Information: Buchanan State Forest, parked vehicle on Aughwick Road, approximately ¼ mile north of Fore Trail.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (11.4 square feet), width (15.5 feet), mean depth (0.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		18	2.29		33	3.47			
2	0.26		19	2.34		34	3.15			
4	0.52		20	2.31		35	2.93			
6	0.74		22	2.25		36	2.73			
8	1.09		23	2.49		37	2.65			
9	1.4		24	2.66		**38***	**2.37***			
10	1.5		25	2.65		43	2.36			
11	1.65		26	3.2		45	2.6			
12	1.83		27	3.7		47	2.42			
13	1.88		28	3.65		49	2.05			
14	1.97		29	3.37		51	1.44			
15	2.06		30	3.29		53	1.07			
16	2.2		31	3.61						
17	2.32		32	3.44						

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 — Time of Survey: 10:12 am

Reach #: 1-B — Drainage Area: 0.74 sq. miles

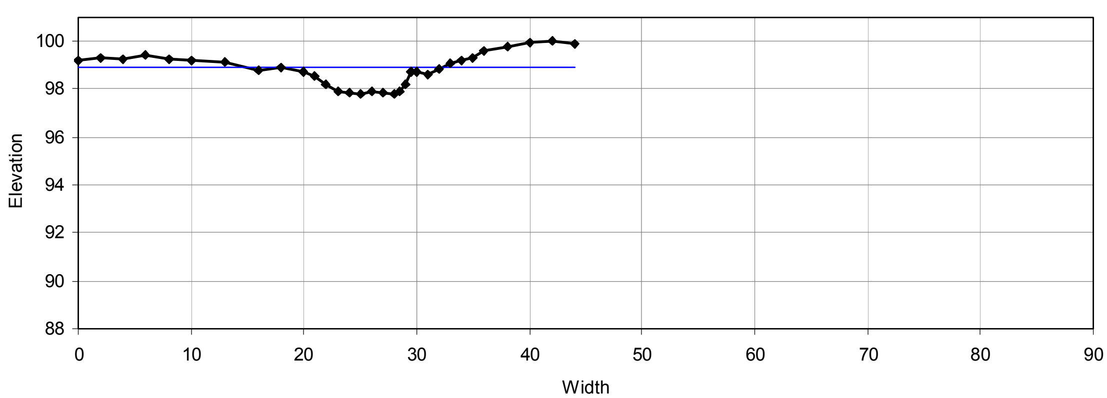
UTM Coordinate Location: Zone 18, 4425800 m N, 0247461 m E

Location Information: Buchanan State Forest, parked vehicle on Aughwick Road, approximately ¼ mile north of Fore Trail, upstream from survey 1-A.

Bankfull Indicator(s): A change in slope along the east channel bank.

Bankfull Response Variables: Cross-sectional area (9.1 square feet), width (14.3 feet), mean depth (0.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.78		25	2.21		38	0.2			
2	0.68		26	2.11		40	0.06			
4	0.73		27	2.16		42	0			
6	0.56		28	2.19		44	0.1			
8	0.72		28.5	2.1						
10	0.78		29	1.8						
13	0.88		29.5	1.3						
16	1.22		30	1.28						
18*	**1.07***		31	1.39						
20	1.25		32	1.13						
21	1.43		33	0.9						
22	1.8		34	0.78						
23	2.1		35	0.68						
24	2.15		36	0.39						

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 Time of Survey: 11:08 am

Reach #: 2-A Drainage Area: 2.08 sq. miles

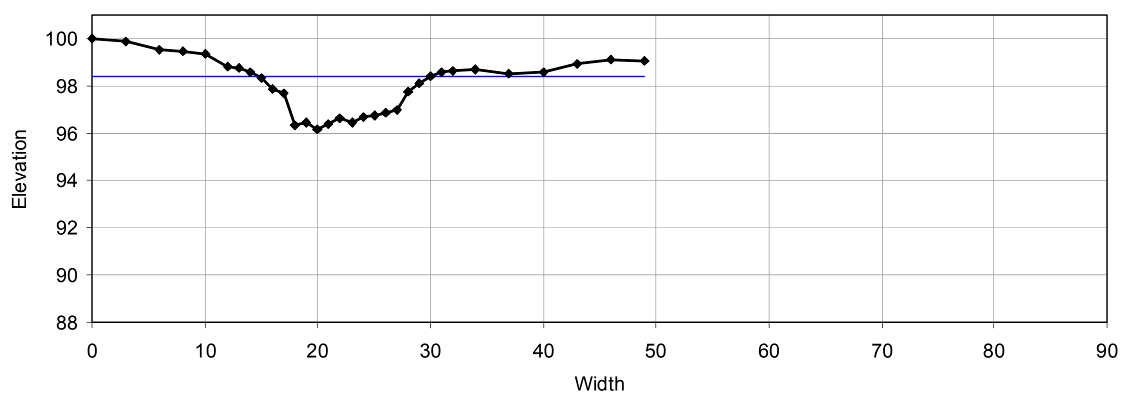
UTM Coordinate Location: Zone 18, 4427286 m N, 0247990 m E

Location Information: Buchanan State Forest, parked vehicle at intersection of Aughwick Road and King's trail, walked upstream.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (9.3 square feet), width (17.6 feet), mean depth (0.5 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		21	3.6		40	1.4			
3	0.1		22	3.4		43	1.04			
6	0.45		23	3.54		46	0.9			
8	0.55		24	3.33		49	0.95			
10	0.65		25	3.26						
12	1.19		26	3.16						
13	1.27		27	3.04						
14	1.43		28	2.24						
15	1.68		29	1.87						
16	2.12		**30***	**1.6***						
17	2.33		31	1.43						
18	3.67		32	1.37						
19	3.54		34	1.29						
20	3.85		37	1.47						

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 Time of Survey: 11:39 am

Reach #: 2-B Drainage Area: 2.08 sq. miles

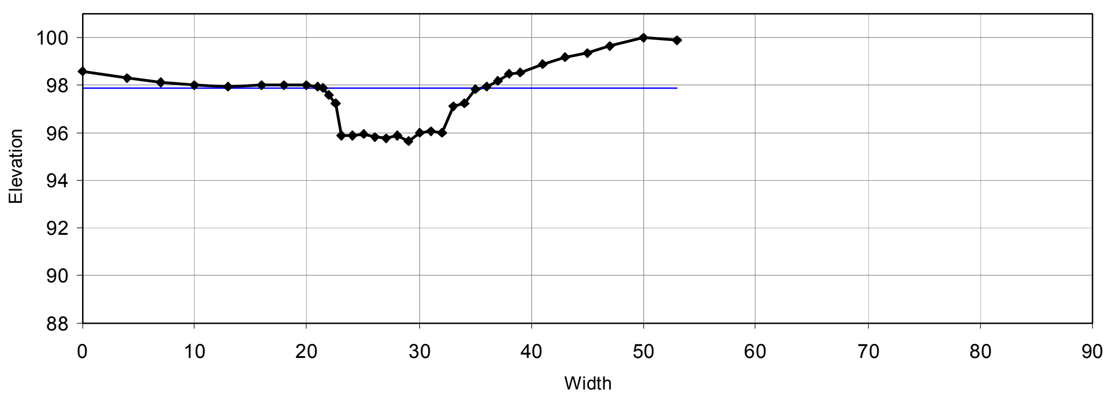
UTM Coordinate Location: Zone 18, 4427256 m N, 0247978 m E

Location Information: Buchanan State Forest, parked vehicle at intersection of Aughwick Road and King's trail. Located upstream from reach 2-A.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (21.2 square feet), width (13.9 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.44		25	4.06		39	1.47			
4	1.68		26	4.2		41	1.13			
7	1.9		27	4.24		43	0.82			
10	2.02		28	4.12		45	0.65			
13	2.07		29	4.33		47	0.37			
16	2.18		30	4		50	0			
18	1.89		31	3.92		53	0.1			
20	2		32	4						
21	2.07		33	2.88						
21.5*	**2.13***		34	2.76						
22	2.4		35	2.19						
22.5	2.74		36	2.03						
23	4.11		37	1.8						
24	4.13		38	1.54						

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 Time of Survey: 12:37 am

Reach #: 3-A Drainage Area: 3.42 sq. miles

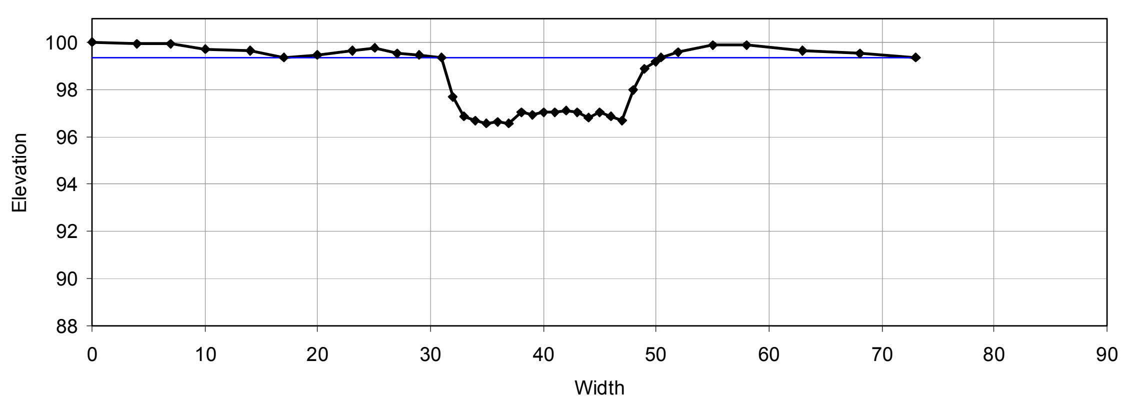
UTM Coordinate Location: Zone 18, 4429045 m N, 0248757 m E

Location Information: Buchanan State Forest, parked vehicle at intersection of Aughwick Road and Crossing Creek Trail, approximately 300 yards downstream of bridge over creek.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (40.5 square feet), width (19.5 feet), mean depth (2.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		34	3.3		48	2			
4	0.05		35	3.42		49	1.1			
7	0.09		36	3.36		50	0.83			
10	0.3		37	3.44		**50.5***	**0.67***			
14	0.35		38	2.96		52	0.39			
17	0.65		39	3.05		55	0.1			
20	0.52		40	2.96		58	0.13			
23	0.35		41	2.97		63	0.35			
25	0.25		42	2.88		68	0.45			
27	0.46		43	2.95		73	0.65			
29	0.55		44	3.2						
31	0.67		45	2.97						
32	2.32		46	3.15						
33	3.11		47	3.33						

South Branch Little Aughwick Creek

Date of Survey: April 30, 2007 Time of Survey: 1:05 pm

Reach #: 3-B Drainage Area: 3.42 sq. miles

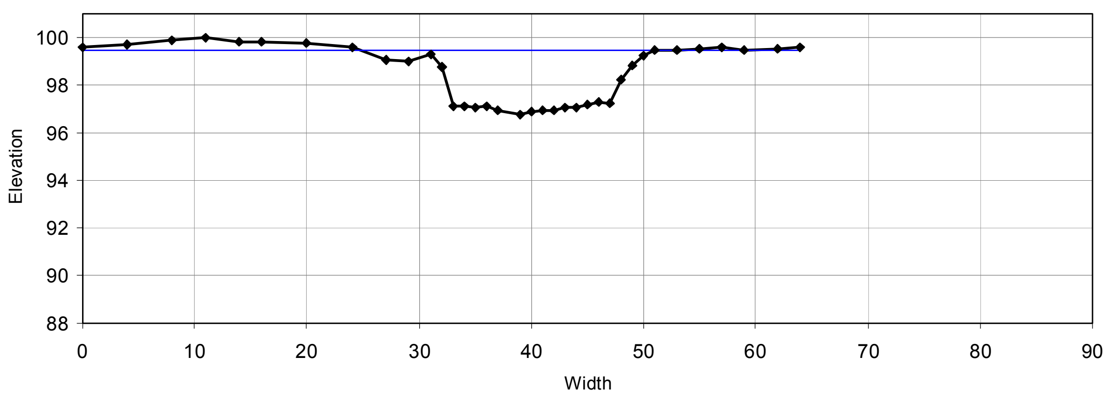
UTM Coordinate Location: Zone 18, 4429065 m N, 0248752 m E

Location Information: Buchanan State Forest, reach located approximately 60 feet downstream from 3-A.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (40.5 square feet), width (19.5 feet), mean depth (2.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.44		35	2.95		50	0.79			
4	0.32		36	2.91		**51***	**0.51***			
8	0.12		37	3.04		53	0.55			
11	0		39	3.24		55	0.45			
14	0.17		40	3.13		57	0.39			
16	0.19		41	3.03		59	0.52			
20	0.22		42	3.06		62	0.48			
24	0.42		43	2.96		64	0.44			
27	0.92		44	2.92		66	0.56			
29	0.99		45	2.85		68	0.37			
31	0.7		46	2.68		70	0.32			
32	1.21		47	2.76						
33	2.86		48	1.74						
34	2.87		49	1.19						

South Branch Little Aughwick Creek

Date of Survey: May 1, 2007 Time of Survey: 10:46 am

Reach #: 4-A Drainage Area: 3.93 sq. miles

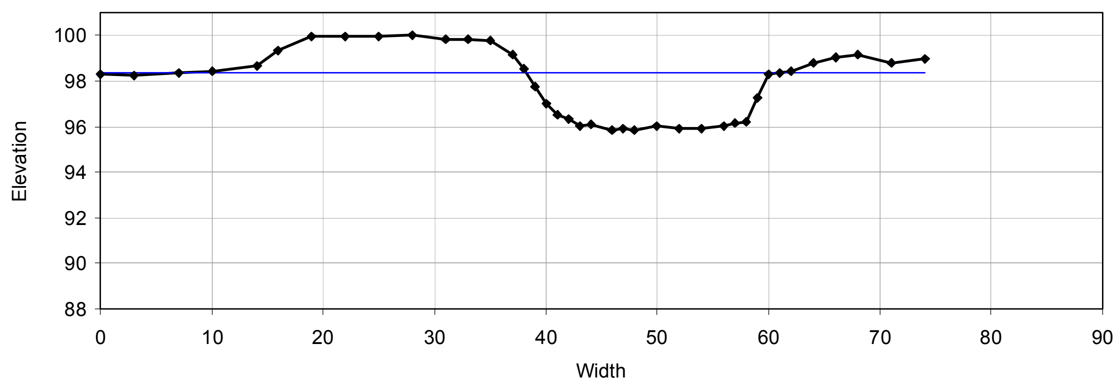
UTM Coordinate Location: Zone 18, 4429787 m N, 0249149 m E

Location Information: Cowan's Gap State Park, parked vehicle at the intersection of Aughwick Road and Camron Trail.

Bankfull Indicator(s): A change in slope along the west to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (44.9 square feet), width (22.7 feet), mean depth (2.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.71		38	1.43		57	3.82			
3	1.73		39	2.22		58	3.76			
7	1.65		40	2.98		59	2.72			
10	1.58		41	3.48		60	1.71			
14	1.36		42	3.67		**61***	**1.63***			
16	0.65		43	3.94		62	1.58			
19	0.06		44	3.9		64	1.23			
22	0.02		46	4.14		66	0.95			
25	0.06		47	4.06		68	0.82			
28	0		48	4.13		71	1.18			
31	0.15		50	3.97		74	1.01			
33	0.17		52	4.07						
35	0.22		54	4.11						
37	0.85		56	3.95						

South Branch Little Aughwick Creek

Date of Survey: May 1, 2007 Time of Survey: 11:24 am

Reach #: 4-B Drainage Area: 3.93 sq. miles

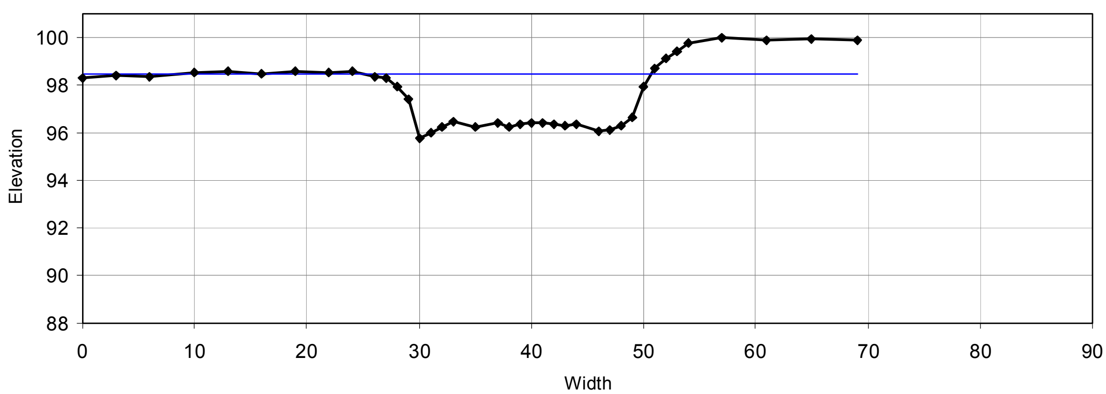
UTM Coordinate Location: Zone 18, 4429825 m N, 0249153 m E

Location Information: Cowan's Gap State Park, parked vehicle at the intersection of Aughwick Road and Camron Trail. Reach located downstream from 4-A.

Bankfull Indicator(s): A change in slope along the east to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (43.4 square feet), width (24.5 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.68		31	4		48	3.68			
3	1.61		32	3.78		49	3.35			
6	1.66		33	3.55		50	2.04			
10	1.47		35	3.78		51	1.27			
13	1.41		37	3.58		52	0.91			
16	1.53		38	3.77		53	0.61			
19	1.39		39	3.66		54	0.26			
22	1.47		40	3.6		57	0			
24	1.43		41	3.6		61	0.12			
26*	**1.64***		42	3.66		65	0.08			
27	1.69		43	3.71		69	0.14			
28	2.08		44	3.64						
29	2.58		46	3.93						
30	4.21		47	3.87						

South Branch Little Aughwick Creek

<u>Date of Survey:</u> May 1, 2007 <u>Time of Survey:</u> 12:37 am

<u>Reach #:</u> 5-A <u>Drainage Area:</u> 4.66 sq. miles

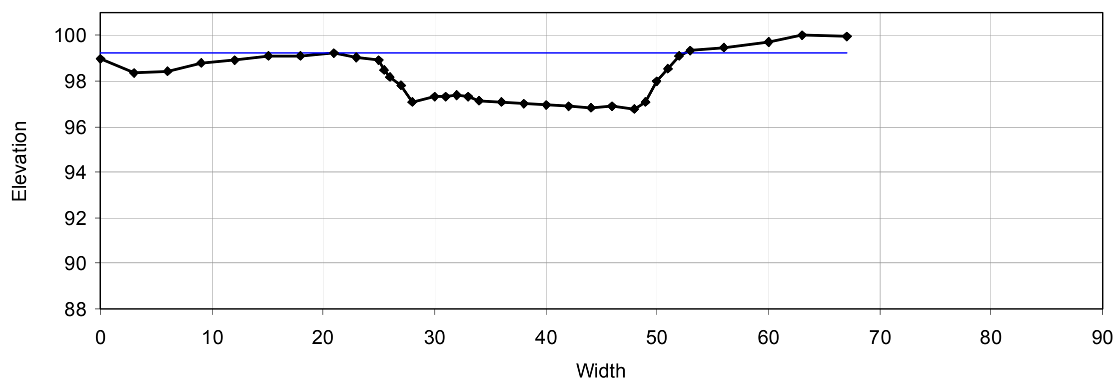
<u>UTM Coordinate Location:</u> Zone 18, 4430894 m N, 0249774 m E

<u>Location Information:</u> Cowan's Gap State Park, parked vehicle in lot near Cabin F, located approximately 1,500 feet upstream of Cowan's Gap Lake.

<u>Bankfull Indicator(s):</u> A change in slope along the west to northwest channel bank.

<u>Bankfull Response Variables:</u> Cross-sectional area (53.4 square feet), width (31.6 feet), mean depth (1.7 feet).

<u>Graph of Channel Cross-Section</u>



<u>Survey Data</u>

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.03		30	2.65		51	1.43			
3	1.64		31	2.7		52	0.89			
6	1.57		32	2.62		53	0.68			
9	1.19		33	2.69		56	0.55			
12	1.08		34	2.84		60	0.27			
15	0.9		36	2.94		63	0			
18	0.88		38	3		67	0.06			
21	0.77		40	3.04						
23	0.96		42	3.13						
25*	**1.08***		44	3.14						
25.5	1.51		46	3.09						
26	1.83		48	3.23						
27	2.2		49	2.9						
28	2.91		50	1.98						

South Branch Little Aughwick Creek

Date of Survey: May 1, 2007 — Time of Survey: 1:01 pm

Reach #: 5-B — Drainage Area: 4.66 sq. miles

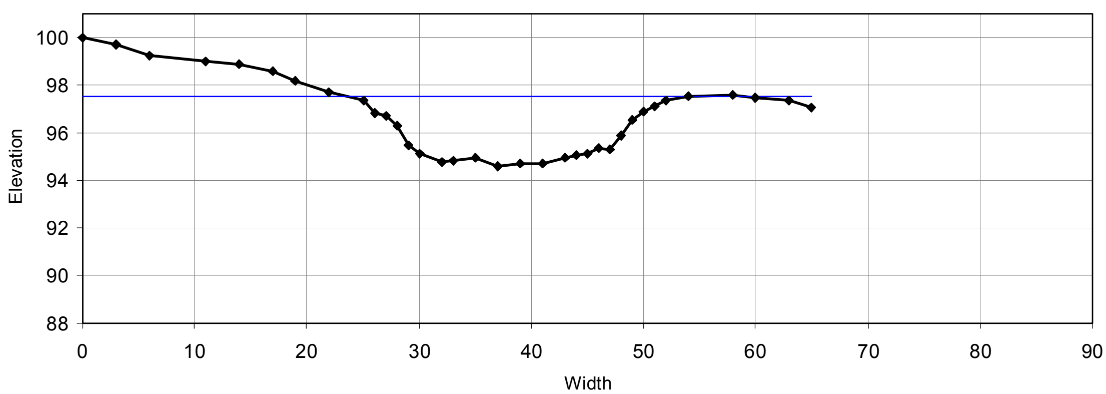
UTM Coordinate Location: Zone 18, 4430706 m N, 0249706 m E

Location Information: Cowan's Gap State Park, parked vehicle in lot near Cabin F, located upstream from reach 5-A.

Bankfull Indicator(s): A change in slope along the west to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (53.4 square feet), width (31.6 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		32	5.23		51	2.91			
3	0.29		33	5.16		52	2.63			
6	0.76		35	5.03		**54***	**2.48***			
11	0.98		37	5.44		58	2.41			
14	1.12		39	5.31		60	2.52			
17	1.44		41	5.31		63	2.67			
19	1.8		43	5.08		65	2.94			
22	2.28		44	4.97						
25	2.67		45	4.89						
26	3.2		46	4.67						
27	3.29		47	4.69						
28	3.7		48	4.13						
29	4.5		49	3.45						
30	4.9		50	3.1						

Sherman Creek

Date of Survey: May 2, 2007 Time of Survey: 11:59 am

Reach #: 6-A Drainage Area: 1.58 sq. miles

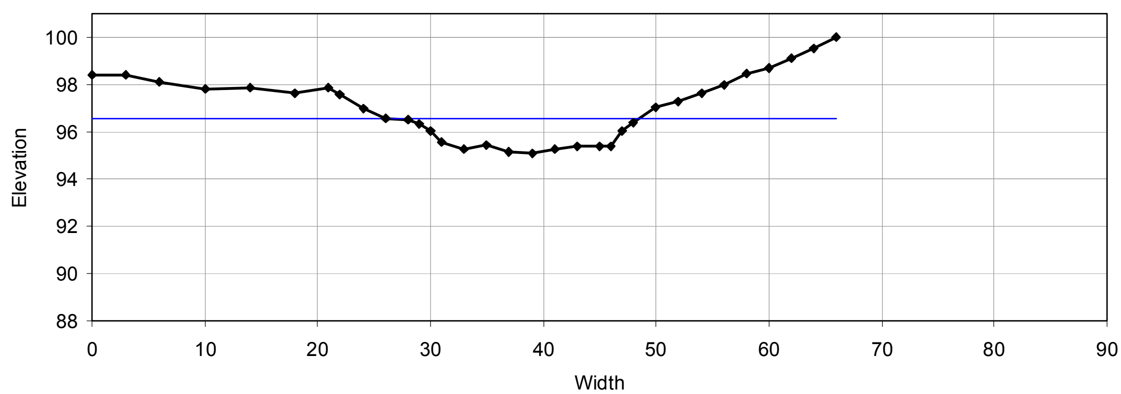
UTM Coordinate Location: Zone 18, 4459394 m N, 0276143 m E

Location Information: Tuscarora State Forest, parked vehicle on Hemlock Road at intersection of Patterson Run Trail. Reach located on Patterson Run in Hemlocks Natural Area.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (21.2 square feet), width (22.4 feet), mean depth (0.9 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.62		33	4.72		58	1.52			
3	1.59		35	4.57		60	1.31			
6	1.89		37	4.86		62	0.88			
10	2.18		39	4.89		64	0.48			
14	2.14		41	4.73		66	0			
18	2.36		43	4.62						
21	2.16		45	4.61						
22	2.4		46	4.61						
24	3		47	3.94						
26*	**3.45***		48	3.59						
28	3.51		50	2.95						
29	3.68		52	2.75						
30	3.99		54	2.35						
31	4.45		56	2.01						

Sherman Creek

Date of Survey: May 2, 2007 Time of Survey: 12:38 am

Reach #: 6-B Drainage Area: 1.58 sq. miles

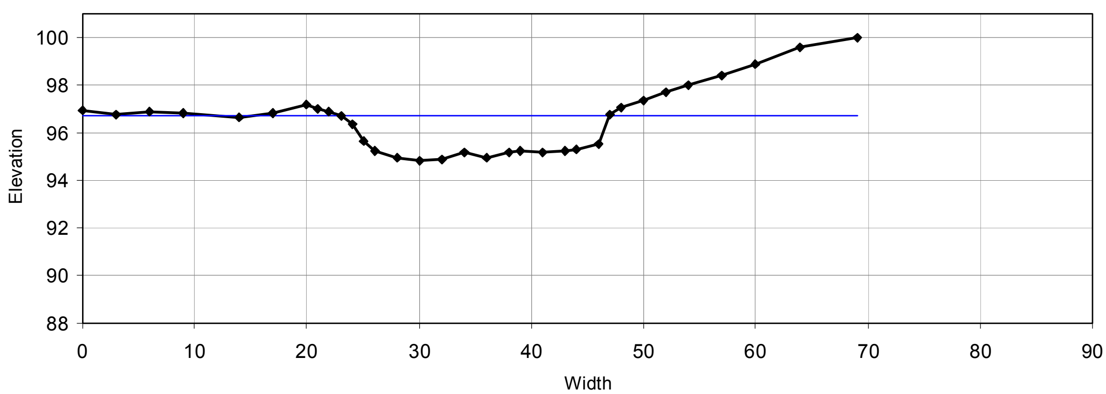
UTM Coordinate Location: Zone 18, 4459397 m N, 0276106 m E

Location Information: Tuscarora State Forest, parked vehicle on Hemlock Road at intersection of Patterson Run Trail. Reach located downstream of 6-A.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (35 square feet), width (23.9 feet), mean depth (1.5 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	3.03		30	5.2		54	2.01			
3	3.24		32	5.14		57	1.6			
6	3.11		34	4.84		60	1.1			
9	3.18		36	5.06		64	0.41			
14	3.35		38	4.83		69	0			
17	3.17		39	4.77						
20	2.81		41	4.81						
21	2.98		43	4.78						
22	3.14		44	4.71						
23*	**3.29***		46	4.45						
24	3.65		47	3.21						
25	4.34		48	2.94						
26	4.78		50	2.65						
28	5.08		52	2.27						

Sherman Creek

Date of Survey: May 2, 2007 Time of Survey: 1:44 pm

Reach #: 7-A Drainage Area: 5.94 sq. miles

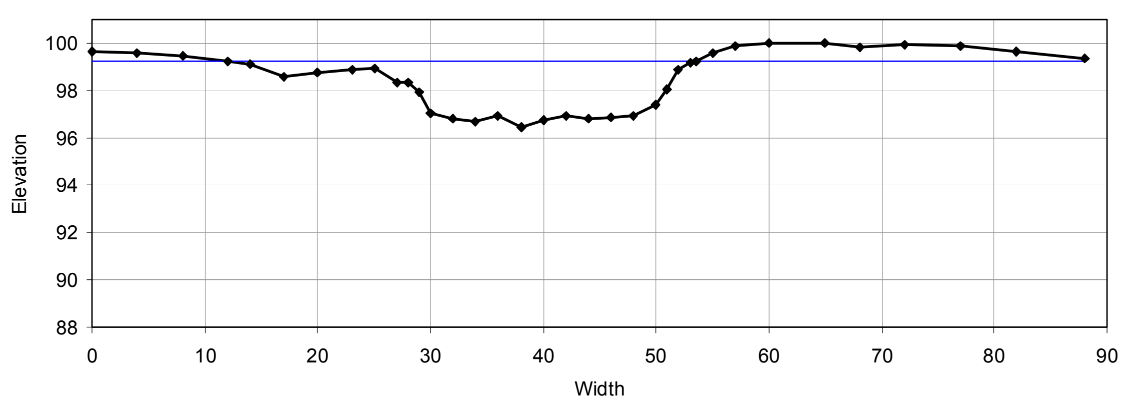
UTM Coordinate Location: Zone 18, 4462068 m N, 0277339 m E

Location Information: Tuscarora State Forest, parked vehicle at bridge on Shearer Doug Road, located off Route 274.

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area (59.9 square feet), width (41.3 feet), mean depth (1.4 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.36		34	3.29		57	0.12			
4	0.4		36	3.08		60	0.02			
8	0.55		38	3.54		65	0			
12	0.76		40	3.25		68	0.21			
14	0.88		42	3.05		72	0.06			
17	1.41		44	3.2		77	0.12			
20	1.26		46	3.13		82	0.33			
23	1.13		48	3.05		88	0.63			
25	1.05		50	2.58						
27	1.63		51	1.98						
28	1.65		52	1.14						
29	2.06		53	0.85						
30	2.97		**53.5***	**0.77***						
32	3.17		55	0.42						

Sherman Creek

Date of Survey: May 2, 2007 | Time of Survey: 2:15 pm

Reach #: 7-B | Drainage Area: 5.94 sq. miles

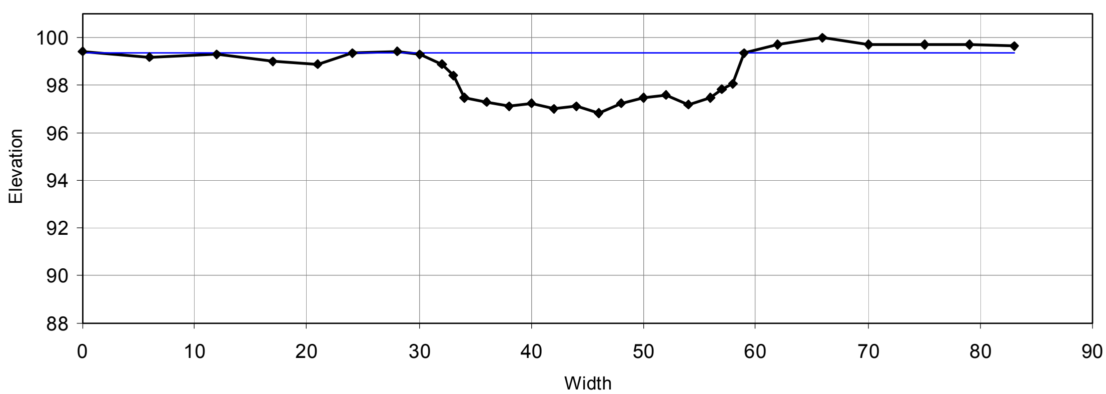
UTM Coordinate Location: Zone 18, 4462075 m N, 0277372 m E

Location Information: Tuscarora State Forest, parked vehicle at bridge on Shearer Doug Road, located off Route 274. Reach located approximately 50 feet downstream of 7-A.

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area – (53.6 square feet), width – (30 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.56		42	2.98		75	0.31			
6	0.82		44	2.88		79	0.28			
12	0.68		46	3.15		83	0.33			
17	0.98		48	2.76						
21	1.11		50	2.55						
24	0.67		52	2.41						
28	0.56		54	2.8						
30	0.68		56	2.53						
32	1.1		57	2.16						
33	1.56		58	1.94						
34	2.53		**59***	**0.62***						
36	2.71		62	0.29						
38	2.86		66	0						
40	2.74		70	0.32						

Sherman Creek

<u>Date of Survey:</u> May 3, 2007   <u>Time of Survey:</u> 8:55 am

<u>Reach #:</u> 8-A   <u>Drainage Area:</u> 1.65 sq. miles

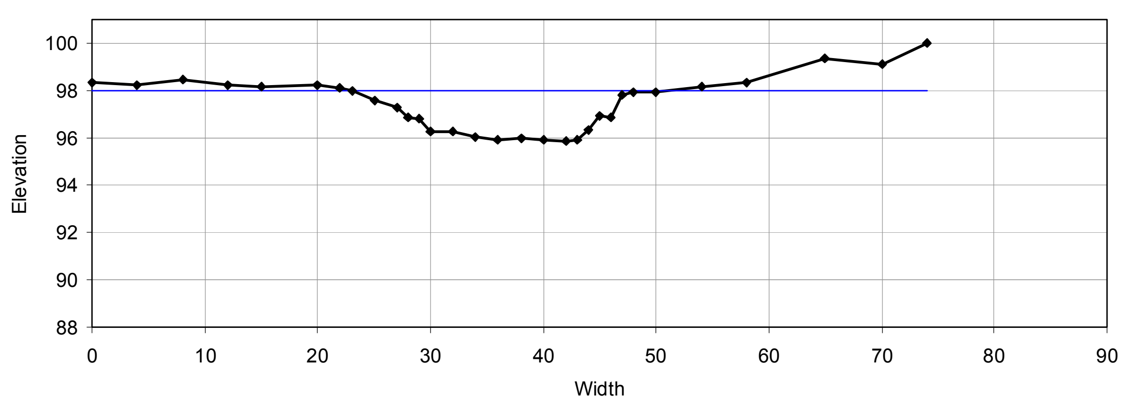
<u>UTM Coordinate Location:</u> Zone 18, 4460998 m N, 0275361 m E

<u>Location Information:</u> Tuscarora State Forest, parked vehicle on Route 274 at a shale pit adjacent to road, at the crest of a small hill. Reach located on Big Spring Run.

<u>Bankfull Indicator(s):</u> A change in slope along the south to southeast channel bank.

<u>Bankfull Response Variables:</u> Cross-sectional area (35.4 square feet), width (27.9 feet), mean depth (1.3 feet).

<u>Graph of Channel Cross-Section</u>



<u>Survey Data</u>

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.67		34	3.94		65	0.67			
4	1.75		36	4.08		70	0.89			
8	1.57		38	4.02		74	0			
12	1.78		40	4.06						
15	1.83		42	4.15						
20	1.76		43	4.11						
22	1.9		44	3.69						
23*	**2.03***		45	3.07						
25	2.4		46	3.15						
27	2.75		47	2.21						
28	3.14		48	2.06						
29	3.2		50	2.09						
30	3.73		54	1.83						
32	3.75		58	1.65						

Sherman Creek

Date of Survey: May 3, 2007 Time of Survey: 9:45 am

Reach #: 8-B Drainage Area: 1.65 sq. miles

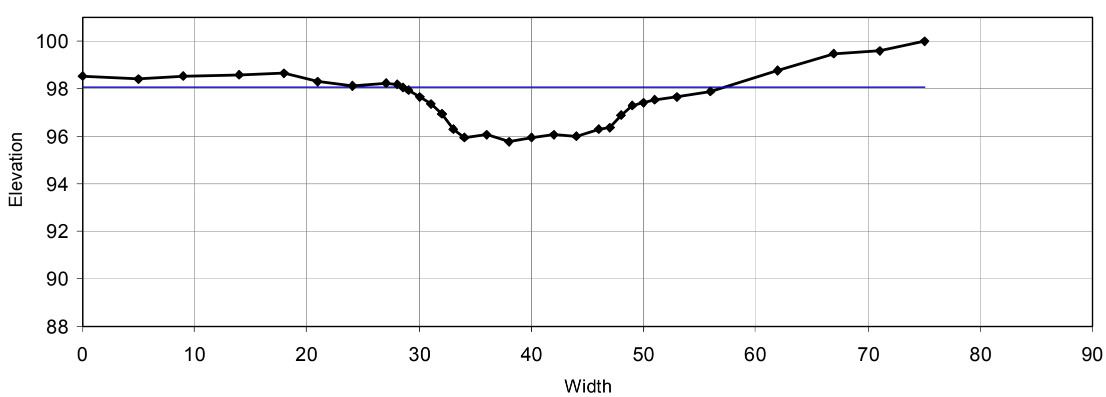
UTM Coordinate Location: Zone 18, 4460977 m N, 0275361 m E

Location Information: Tuscarora State Forest, parked vehicle on Route 274 at a shale pit adjacent to road, at the crest of a small hill. Reach located approximately 100 feet upstream of 8-A.

Bankfull Indicator(s): A change in slope along the south to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (37 square feet), width (28.7 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.45		33	3.7		56	2.12			
5	1.56		34	4.05		62	1.25			
9	1.46		36	3.96		67	0.55			
14	1.39		38	4.21		71	0.41			
18	1.34		40	4.07		75	0			
21	1.69		42	3.94						
24	1.91		44	3.98						
27	1.74		46	3.72						
28	1.82		47	3.64						
28.5*	**1.95***		48	3.09						
29	2.04		49	2.73						
30	2.33		50	2.6						
31	2.65		51	2.45						
32	3.08		53	2.33						

Sherman Creek

Date of Survey: May 3, 2007 Time of Survey: 10:35 am

Reach #: 9-A Drainage Area: 8.25 sq. miles

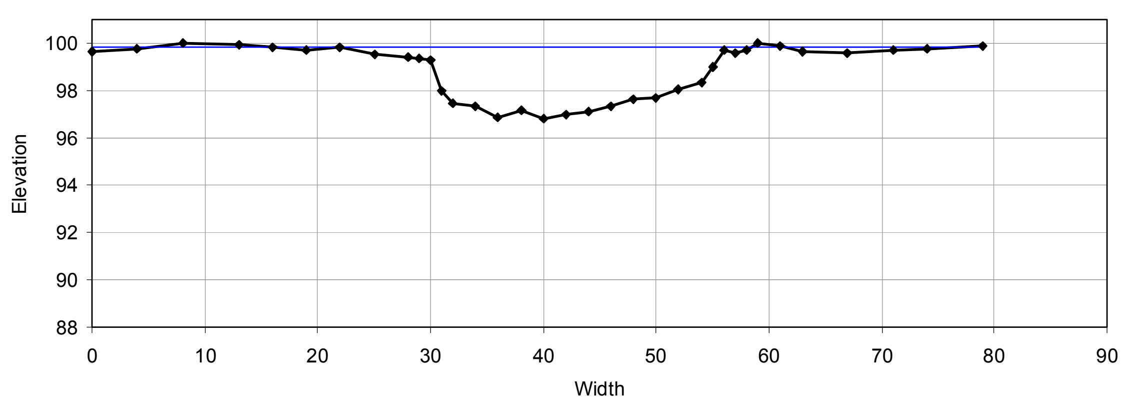
UTM Coordinate Location: Zone 18, 4463005 m N, 0278571 m E

Location Information: Tuscarora State Forest, parked vehicle on Route 274, approximately ¼ mile north of Fairview Church at the intersection of Iron Horse Trail.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (60.8 square feet), width (36.3 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0.33	36	3.12	59	0.03		
4	0.24	38	2.86	61	0.1		
8	0	40	3.18	63	0.35		
13	0.04	42	3	67	0.43		
16	0.2	44	2.89	71	0.3		
19	0.31	46	2.65	74	0.22		
22*	**0.21***	48	2.35	79	0.12		
25	0.48	50	2.29				
28	0.59	52	1.93				
29	0.65	54	1.65				
30	0.71	55	1				
31	2	56	0.29				
32	2.53	57	0.44				
34	2.66	58	0.3				

Sherman Creek

Date of Survey: May 3, 2007 Time of Survey: 11:08 am

Reach #: 9-B Drainage Area: 8.25 sq. miles

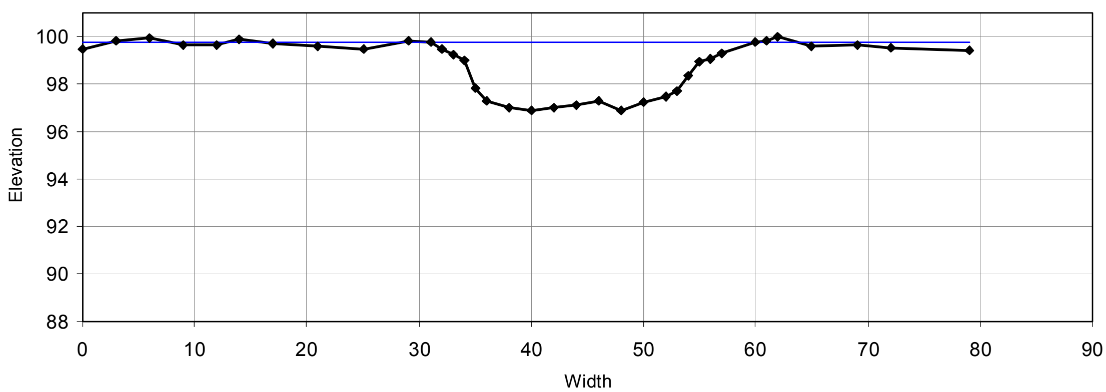
UTM Coordinate Location: Zone 18, 4463007 m N, 0278568 m E

Location Information: Tuscarora State Forest, parked vehicle on Route 274, approximately ¼ mile north of Fairview Church at the intersection of Iron Horse Trail. Reach located upstream of 9-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (53.6 square feet), width (28.9 feet), mean depth (1.9 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.51		35	2.17		57	0.71			
3	0.17		36	2.68		60	0.24			
6	0.04		38	3		61	0.17			
9	0.34		40	3.1		62	0			
12	0.37		42	2.98		65	0.4			
14	0.14		44	2.87		69	0.38			
17	0.28		46	2.72		72	0.48			
21	0.39		48	3.1		79	0.57			
25	0.51		50	2.77						
29	0.19		52	2.53						
31*	**0.26***		53	2.28						
32	0.51		54	1.65						
33	0.77		55	1.05						
34	0.98		56	0.97						

Sherman Creek

Date of Survey: May 3, 2007 Time of Survey: 12:07 am

Reach #: 10-A Drainage Area: 10.06 sq. miles

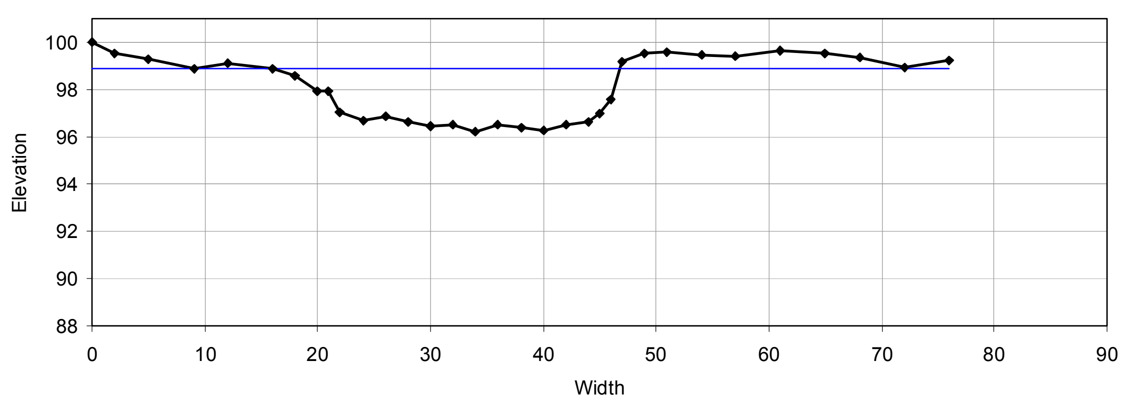
UTM Coordinate Location: Zone 18, 4463007 m N, 0278568 m E

Location Information: Located on private property with public fishing access, on Buck Ridge Road, off of Route 274.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (60.2 square feet), width (30.8 feet), mean depth (2.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0	32	3.48	61	0.37		
2	0.48	34	3.81	65	0.46		
5	0.72	36	3.51	68	0.65		
9	1.15	38	3.59	72	1.07		
12	0.89	40	3.72	76	0.76		
16*	**1.11***	42	3.52				
18	1.44	44	3.35				
20	2.09	45	3				
21	2.08	46	2.4				
22	2.97	47	0.82				
24	3.31	49	0.48				
26	3.14	51	0.41				
28	3.39	54	0.53				
30	3.55	57	0.59				

Sherman Creek

Date of Survey: May 9, 2007 Time of Survey: 3:19 pm

Reach #: 11-A Drainage Area: 1.01 sq. miles

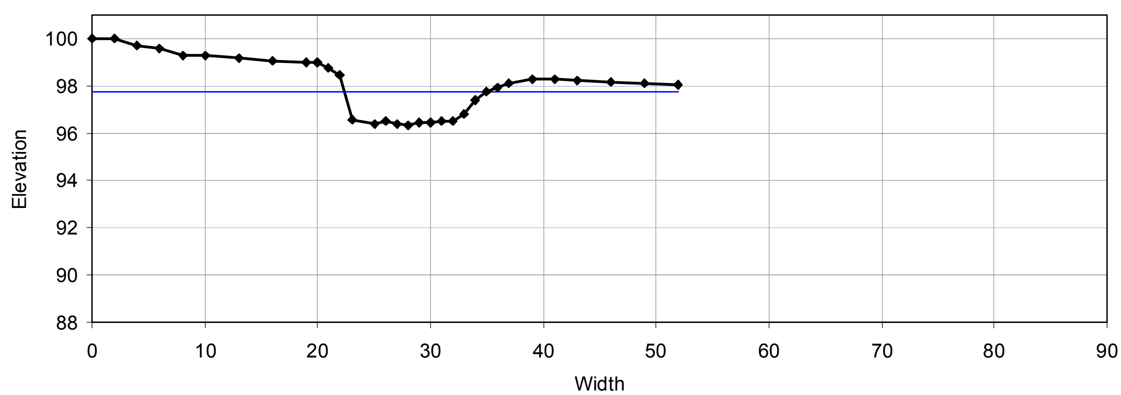
UTM Coordinate Location: Zone 18, 4460667 m N, 0274457 m E

Location Information: Tuscarora State Forest, east of Big Spring State Park. Reach located on Big Spring Run

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area (14 square feet), width (12.6 feet), mean depth (1.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		26	3.49		43	1.79			
2	0.03		27	3.58		46	1.81			
4	0.3		28	3.64		49	1.9			
6	0.39		29	3.56		52	1.94			
8	0.69		30	3.53						
10	0.71		31	3.49						
13	0.86		32	3.47						
16	0.95		33	3.22						
19	0.98		34	2.6						
20	1.02		**35***	**2.25***						
21	1.24		36	2.08						
22	1.56		37	1.92						
23	3.45		39	1.74						
25	3.63		41	1.72						

Sherman Creek

Date of Survey: May 9, 2007 | Time of Survey: 3:47 pm

Reach #: 11-B | Drainage Area: 1.01 sq. miles

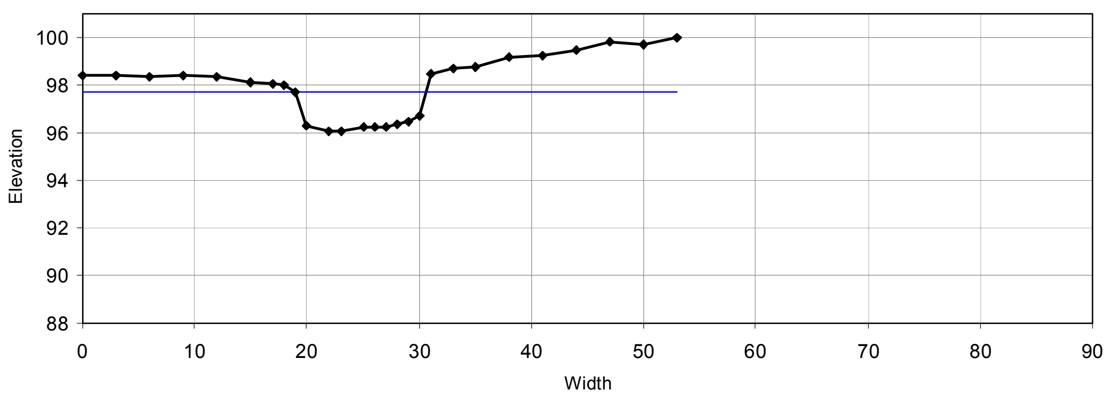
UTM Coordinate Location: Zone 18, 4460667 m N, 0274457 m E

Location Information: Tuscarora State Forest, east of Big Spring State Park. Reach located on Big Spring Run, downstream approximately 25 feet from 11-A.

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area (15.4 square feet), width (11.5 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	1.6	27	3.77				
3	1.59	28	3.65				
6	1.67	29	3.54				
9	1.61	30	3.29				
12	1.65	31	1.5				
15	1.86	33	1.31				
17	1.94	35	1.25				
18	2	38	0.8				
19*	**2.32***	41	0.79				
20	3.71	44	0.55				
22	3.94	47	0.2				
23	3.97	50	0.29				
25	3.79	53	0				
26	3.79						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 9:52 am

Reach #: 12-A Drainage Area: 4.38 sq. miles

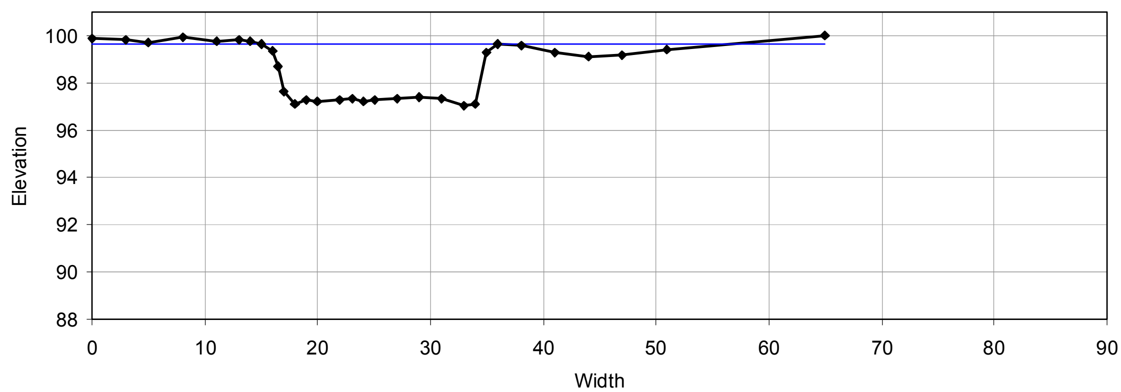
UTM Coordinate Location: Zone 18, 4465254 m N, 0276218 m E

Location Information: Tuscarora State Forest, parked vehicle on Horse Valley Road.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (53.4 square feet), width (31.6 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0.1	22	2.7	47	0.86		
3	0.2	23	2.65	51	0.58		
5	0.3	24	2.78	65	0		
8	0.05	25	2.71				
11	0.23	27	2.64				
13	0.18	29	2.58				
14	0.23	31	2.66				
15*	**0.35***	33	2.93				
16	0.68	34	2.92				
16.5	1.33	35	0.74				
17	2.39	36	0.36				
18	2.89	38	0.43				
19	2.71	41	0.71				
20	2.81	44	0.87				

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 10:03 am

Reach #: 12-B Drainage Area: 4.38 sq. miles

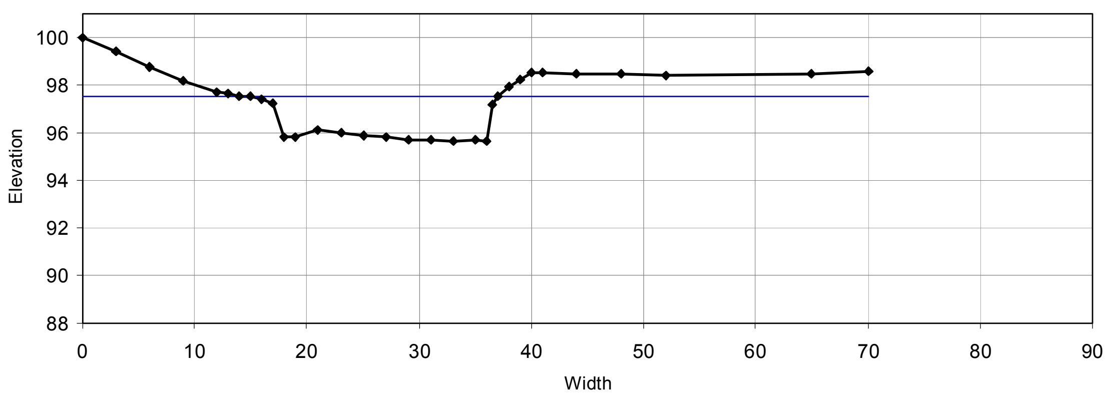
UTM Coordinate Location: Zone 18, 4465262 m N, 0276227 m E

Location Information: Tuscarora State Forest, parked vehicle on Horse Valley Road. Reach located downstream from survey 12-A.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (33.1 square feet), width (23.4 feet), mean depth (1.4 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		25	4.11		48	1.54			
3	0.61		27	4.15		52	1.56			
6	1.25		29	4.3		65	1.53			
9	1.83		31	4.31		70	1.44			
12	2.29		33	4.33						
13	2.37		35	4.29						
14	2.48		36	4.38						
15*	**2.45***		36.5	2.81						
16	2.56		37	2.49						
17	2.78		38	2.08						
18	4.19		39	1.77						
19	4.18		40	1.49						
21	3.87		41	1.45						
23	4.01		44	1.52						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 11:28 am

Reach #: 13-A Drainage Area: 13.9 sq. miles

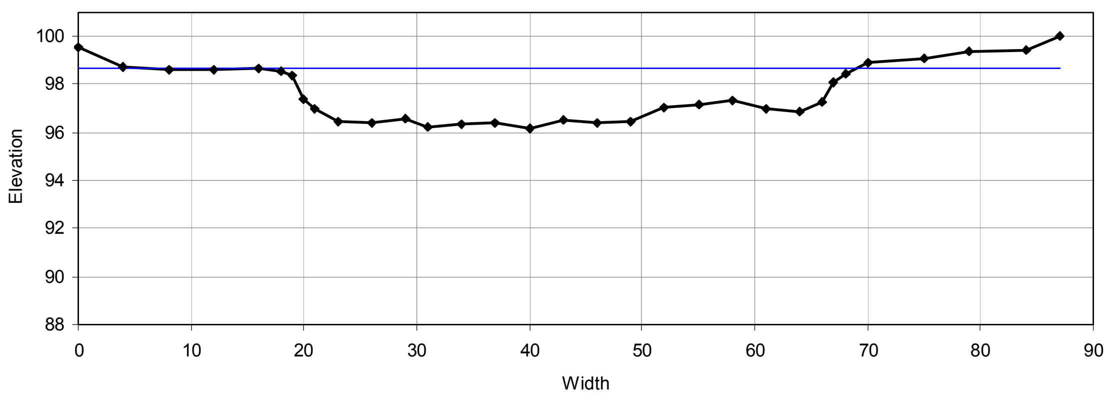
UTM Coordinate Location: Zone 18, 4469394 m N, 0279428 m E

Location Information: Tuscarora State Forest, parked vehicle on Horse Valley Road, located at the water gap.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (116.9 square feet), width (52.6 feet), mean depth (2.2 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.5		43	5.9		74	2.76			
4	1.52		46	5.66		76	2.61			
9	1.69		48	5.53		79	2.28			
12	2.52		51	5.31		82	1.68			
15	2.71		53	5.32		86	1.3			
19	2.7		56	4.96		90	1.06			
21*	**2.93***		59	4.87		94	0.53			
23	3.56		62	4.93		98	0			
25	4.81		65	5.24						
27	5.53		68	5.15						
30	5.55		70	5.08						
34	5.56		71	4.58						
37	5.63		72	3.87						
40	5.71		73	3.2						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 12:00 am

Reach #: 13-B Drainage Area: 13.9 sq. miles

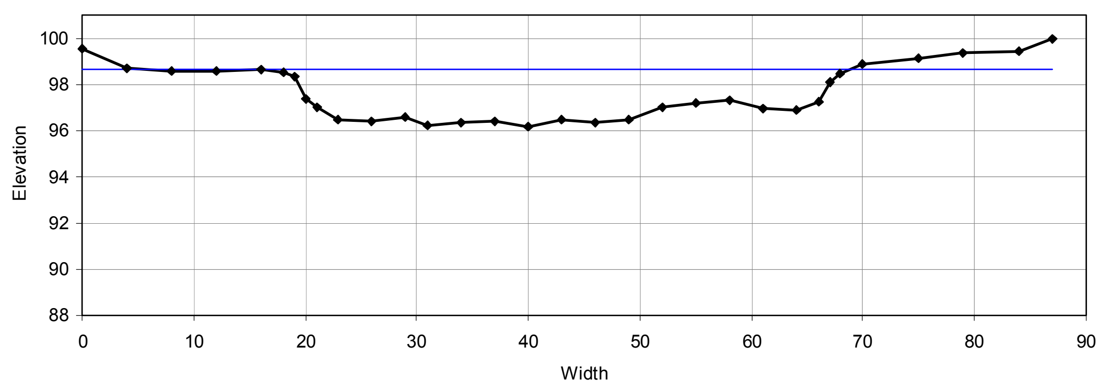
UTM Coordinate Location: Zone 18, 4469406 m N, 0279414 m E

Location Information: Tuscarora State Forest, reach located approximately 100 feet downstream from survey 2-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (95.7 square feet), width (53 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.45		37	3.61		75	0.9			
4	1.27		40	3.86		79	0.65			
8	1.4		43	3.51		84	0.58			
12	1.41		46	3.63		87	0			
16	1.33		49	3.55						
18	1.45		52	2.97						
19*	**1.65***		55	2.83						
20	2.6		58	2.69						
21	3.02		61	3.05						
23	3.56		64	3.11						
26	3.59		66	2.76						
29	3.41		67	1.92						
31	3.8		68	1.55						
34	3.68		70	1.1						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 1:04 pm

Reach #: 14-A Drainage Area: 4.98 sq. miles

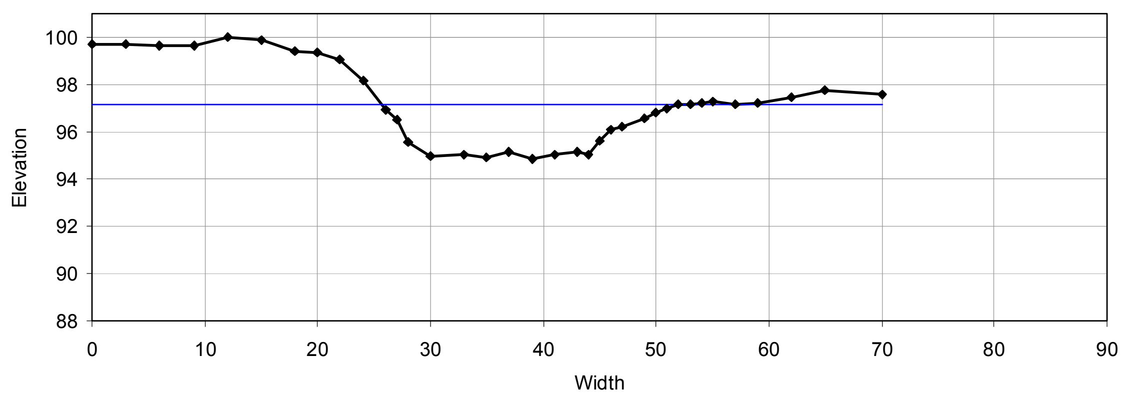
UTM Coordinate Location: Zone 18, 4469188 m N, 0280073 m E

Location Information: Tuscarora State Forest, parked vehicle on Horse Valley Road near confluence of Horse Valley Run and Kansas Valley Run. Measured reach on Kansas Valley Run.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (41.3 square feet), width (26.3 feet), mean depth (1.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.31		33	4.95		53	2.83			
3	0.31		35	5.08		54	2.78			
6	0.33		37	4.85		55	2.74			
9	0.34		39	5.13		57	2.85			
12	0		41	4.97		59	2.81			
15	0.15		43	4.87		62	2.55			
18	0.62		44	4.95		65	2.27			
20	0.68		45	4.39		70	2.4			
22	0.93		46	3.9						
24	1.83		47	3.76						
26	3.06		49	3.44						
27	3.47		50	3.2						
28	4.43		51	3.03						
30	5		**52***	**2.86***						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 1:32 pm

Reach #: 14-B Drainage Area: 4.98 sq. miles

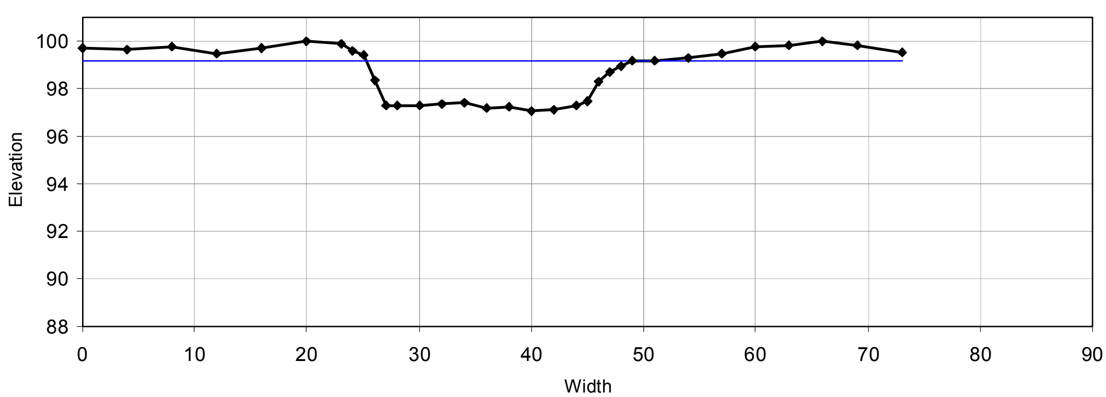
UTM Coordinate Location: Zone 18, 4469183 m N, 0280067 m E

Location Information: Tuscarora State Forest, parked vehicle on Horse Valley Road near confluence of Horse Valley Run and Kansas Valley Run. Reach located downstream of survey 14-B.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (38 square feet), width (23.7 feet), mean depth (1.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.32		34	2.6		60	0.21			
4	0.37		36	2.83		63	0.2			
8	0.21		38	2.77		66	0.01			
12	0.52		40	2.93		69	0.16			
16	0.31		42	2.89		73	0.48			
20	0		44	2.69						
23	0.13		45	2.54						
24	0.41		46	1.71						
25	0.57		47	1.28						
26	1.67		48	1.05						
27	2.68		**49***	**0.85***						
28	2.71		51	0.83						
30	2.68		54	0.72						
32	2.62		57	0.54						

Horse Valley Run

Date of Survey: May 10, 2007 Time of Survey: 2:26 pm

Reach #: 15-A Drainage Area: 3.88 sq. miles

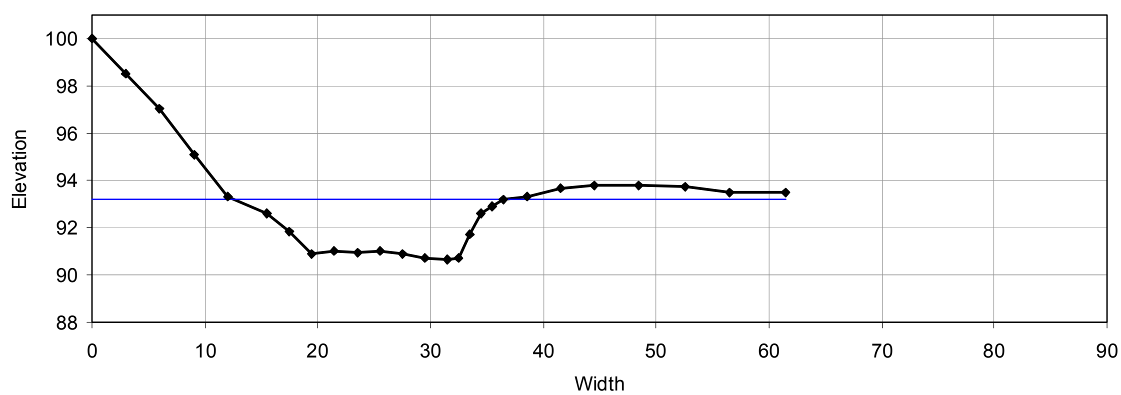
UTM Coordinate Location: Zone 18, 4469481 m N, 0280978 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road. Reach located on Kansas Valley Run.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (27.7 square feet), width (19 feet), mean depth (1.5 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		32.5	9.29						
3	1.47		33.5	8.29						
6	2.96		34.5	7.39						
9	4.88		35.5	7.11						
12	6.67		**36.5***	**6.81***						
15.5	7.38		38.5	6.69						
17.5	8.16		41.5	6.31						
19.5	9.1		44.5	6.2						
21.5	8.99		48.5	6.23						
23.5	9.05		52.5	6.24						
25.5	9		56.5	6.5						
27.5	9.11		61.5	6.51						
29.5	9.28									
31.5	9.37									

Horse Valley Run

Date of Survey: May 10, 2007 | Time of Survey: 2:41 pm

Reach #: 15-B | Drainage Area: 3.88 sq. miles

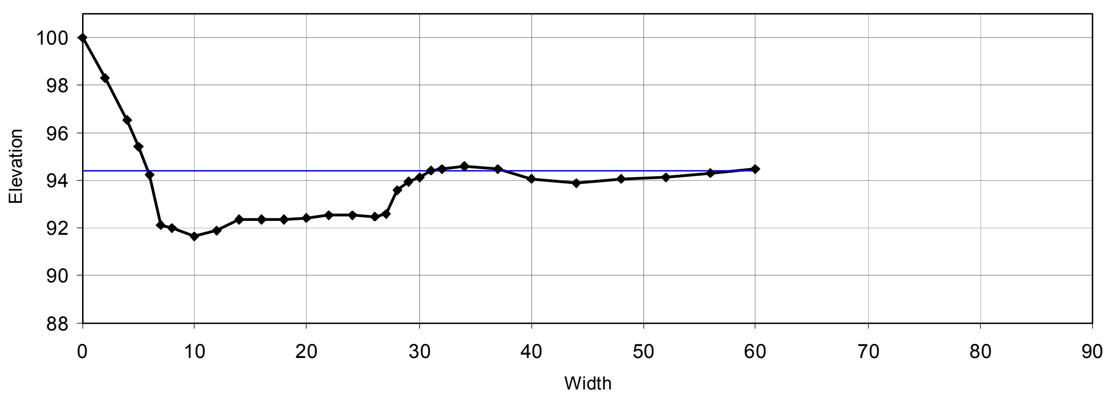
UTM Coordinate Location: Zone 18, 4469562 m N, 0281022 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road. Reach located on Kansas Valley Run. Reach located downstream from 15-A.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (36.1 square feet), width (22.9 feet), mean depth (1.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0	24	7.47	56	5.7		
2	1.73	26	7.54	60	5.53		
4	3.45	27	7.43				
5	4.61	28	6.42				
6	5.74	**29***	**6.03***				
7	7.89	30	5.87				
8	8.02	31	5.59				
10	8.33	32	5.55				
12	8.11	34	5.43				
14	7.64	37	5.54				
16	7.66	40	5.97				
18	7.62	44	6.1				
20	7.58	48	5.96				
22	7.48	52	5.88				

Horse Valley Run

Date of Survey: May 11, 2007 Time of Survey: 2:19 pm

Reach #: 16-A Drainage Area: 2.91 sq. miles

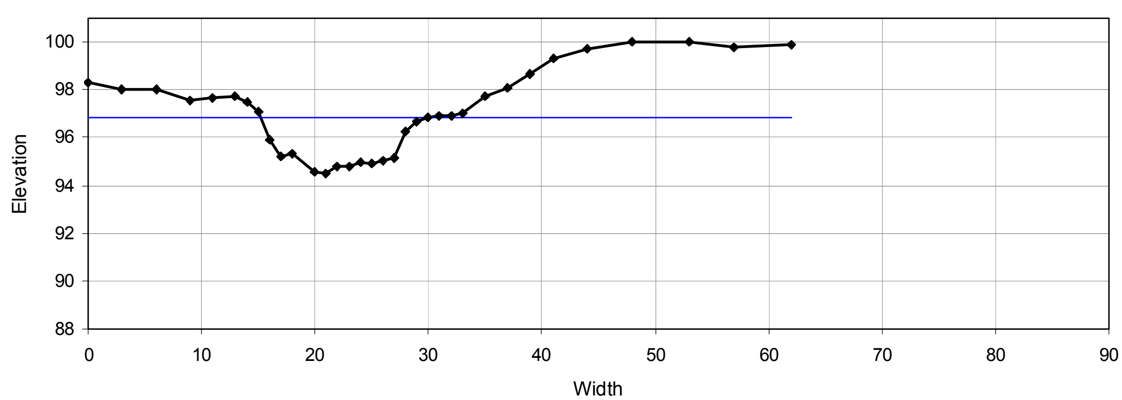
UTM Coordinate Location: Zone 18, 4470293 m N, 0281655 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road. Reach located on Kansas Valley Run, upstream from active forest clearing operation.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (23 square feet), width (14.8 feet), mean depth (1.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.71		23	5.18		41	0.68			
3	1.96		24	5.03		44	0.28			
6	2		25	5.07		48	0			
9	2.43		26	4.97		53	0			
11	2.32		27	4.85		57	0.22			
13	2.25		28	3.76		62	0.1			
14	2.52		29	3.33						
15	2.9		**30***	**3.13***						
16	4.07		31	3.12						
17	4.77		32	3.12						
18	4.69		33	3						
20	5.46		35	2.28						
21	5.49		37	1.91						
22	5.21		39	1.32						

Horse Valley Run

Date of Survey: May 11, 2007 Time of Survey: 2:34 pm

Reach #: 16-B Drainage Area: 2.91 sq. miles

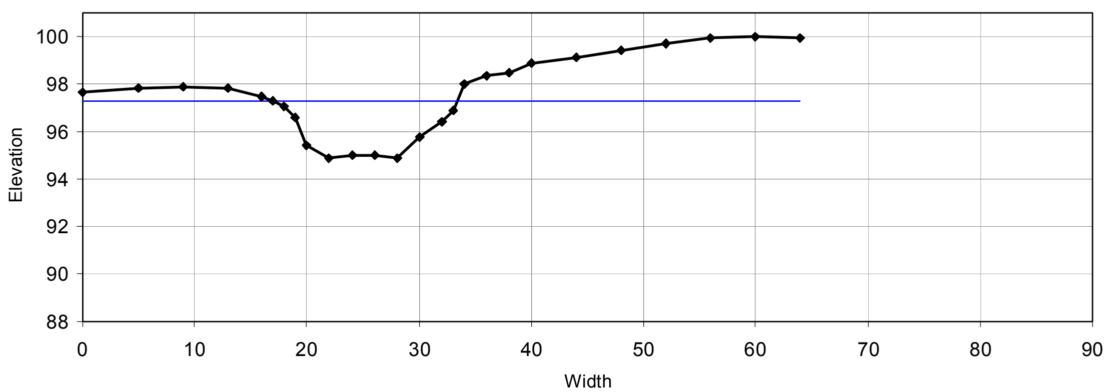
UTM Coordinate Location: Zone 18, 4470266 m N, 0281647 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road. Reach located on Kansas Valley Run, approximately 150 feet downstream from reach 16-A.

Bankfull Indicator(s): A change in slope along the east channel bank.

Bankfull Response Variables: Cross-sectional area (27.7 square feet), width (16.4 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	2.34		32	3.58						
5	2.15		33	3.13						
9	2.09		34	2.01						
13	2.18		36	1.62						
16	2.5		38	1.54						
17*	**2.68***		40	1.14						
18	2.97		44	0.9						
19	3.44		48	0.59						
20	4.57		52	0.32						
22	5.11		56	0.03						
24	4.99		60	0						
26	5		64	0.06						
28	5.11									
30	4.26									

Horse Valley Run

Date of Survey: May 11, 2007 Time of Survey: 3:37 pm

Reach #: 17-A Drainage Area: 1.54 sq. miles

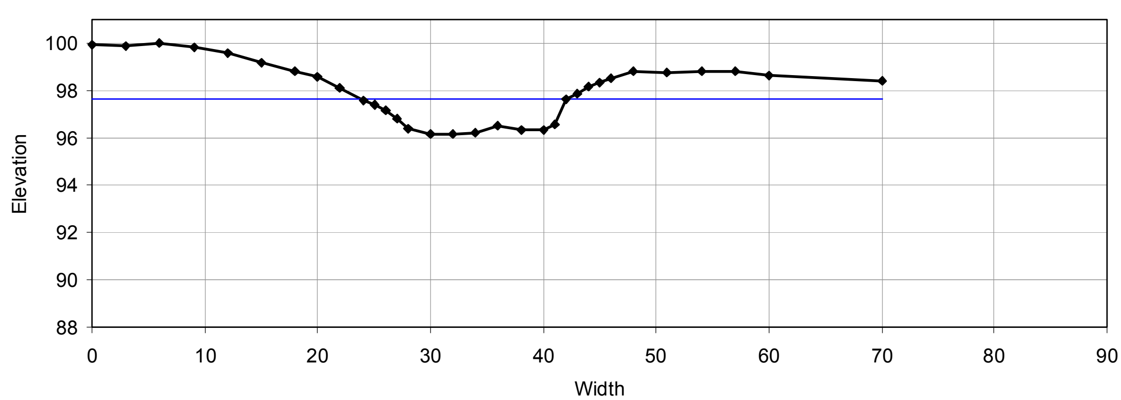
UTM Coordinate Location: Zone 18, 4470482 m N, 0282011 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road near intersection with Kansas Loop Road. Reach located on Kansas Valley Run.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (20.3 square feet), width (18.2 feet), mean depth (1.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.05		30	3.87		54	1.2			
3	0.12		32	3.86		57	1.17			
6	0		34	3.79		60	1.37			
9	0.2		36	3.5		70	1.59			
12	0.42		38	3.69						
15	0.81		40	3.65						
18	1.16		41	3.43						
20	1.44		**42***	**2.36***						
22	1.88		43	2.13						
24	2.4		44	1.86						
25	2.61		45	1.63						
26	2.85		46	1.48						
27	3.22		48	1.21						
28	3.59		51	1.24						

Horse Valley Run

Date of Survey: May 11, 2007 | Time of Survey: 3:55 pm

Reach #: 17-B | Drainage Area: 1.54 sq. miles

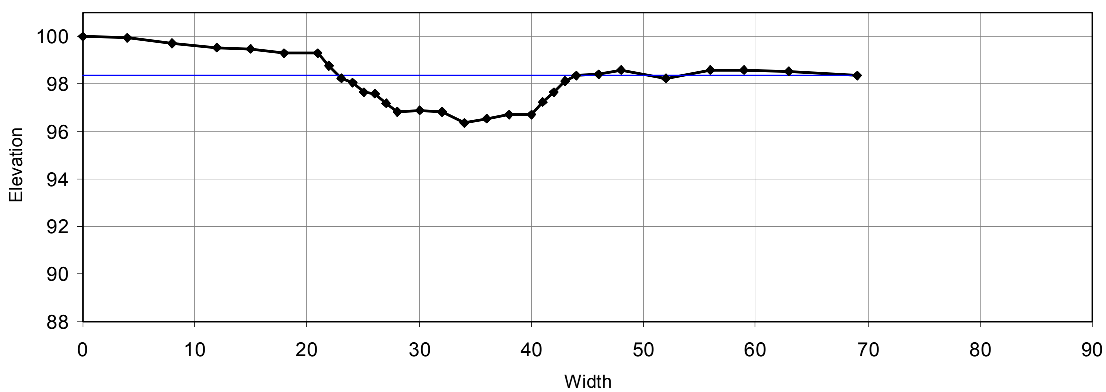
UTM Coordinate Location: Zone 18, 4470482 m N, 0282011 m E

Location Information: Tuscarora State Forest, parked vehicle on Kansas Valley Road near intersection with Kansas Loop Road. Reach located approximately 50 feet downstream of 17-A.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (26.7 square feet), width (21.2 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		30	3.13		59	1.4			
4	0.03		32	3.2		63	1.47			
8	0.27		34	3.64		69	1.66			
12	0.49		36	3.45						
15	0.52		38	3.31						
18	0.68		40	3.28						
21	0.73		41	2.75						
22	1.23		42	2.36						
23	1.74		43	1.88						
24	1.94		**44***	**1.65***						
25	2.35		46	1.58						
26	2.4		48	1.41						
27	2.84		52	1.76						
28	3.18		56	1.42						

Laurel Run

Date of Survey: May 12, 2007 Time of Survey: 11:07 am

Reach #: 18-A Drainage Area: 1.43 sq. miles

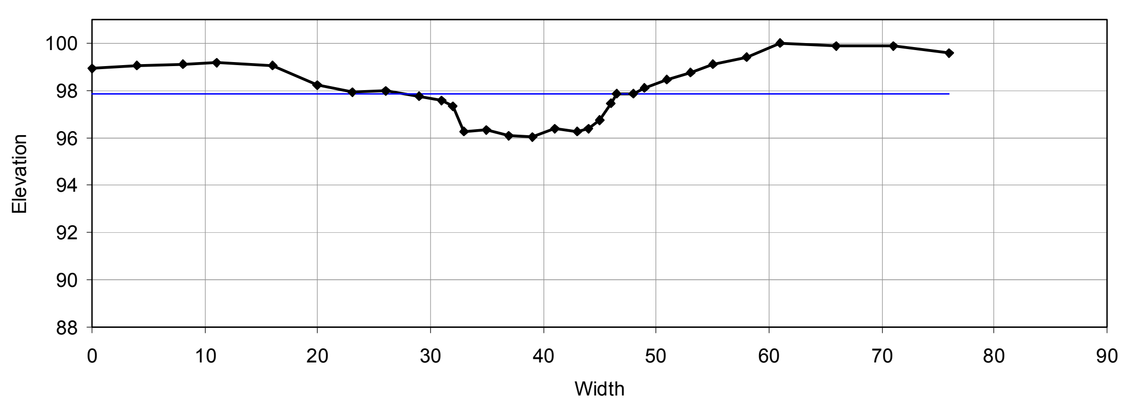
UTM Coordinate Location: Zone 18, 4455788 m N, 0281538 m E

Location Information: Tuscarora State Forest, parked vehicle along Three Square Hollow Road at the intersection of Tuscarora Trail.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (22.3 square feet), width (19.2 feet), mean depth (1.2 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.07		39	3.96		66	0.14			
4	0.96		41	3.62		71	0.1			
8	0.87		43	3.75		76	0.4			
11	0.83		44	3.58						
16	0.96		45	3.26						
20	1.79		46	2.57						
23	2.08		**46.5***	**2.13***						
26	2.02		48	2.12						
29	2.27		49	1.91						
31	2.42		51	1.56						
32	2.64		53	1.24						
33	3.75		55	0.92						
35	3.67		58	0.61						
37	3.91		61	0						

Laurel Run

Date of Survey: May 12, 2007 Time of Survey: 11:23 am

Reach #: 18-B Drainage Area: 1.43 sq. miles

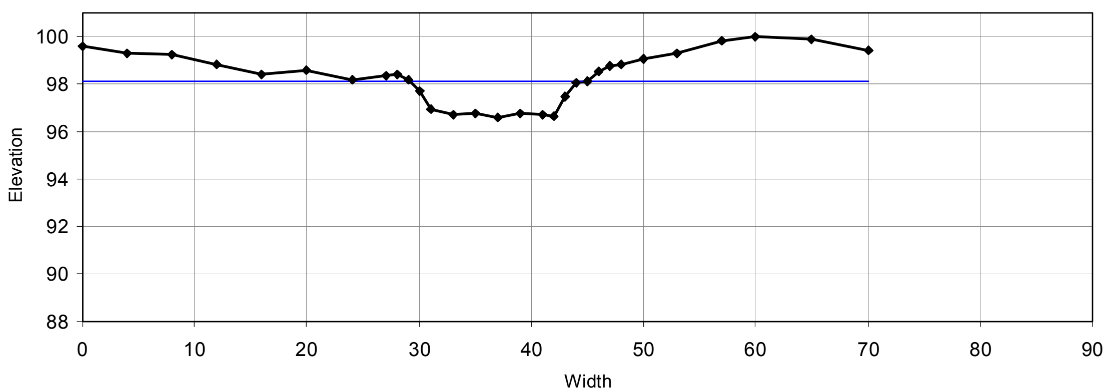
UTM Coordinate Location: Zone 18, 4455800 m N, 0281525 m E

Location Information: Tuscarora State Forest, parked vehicle along Three Square Hollow Road at the intersection of Tuscarora Trail. Reach located approximately 50 feet downstream of 18-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (18.0 square feet), width (16.0 feet), mean depth (1.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.44		37	3.41		65	0.11			
4	0.7		39	3.25		70	0.59			
8	0.76		41	3.31						
12	1.17		42	3.35						
16	1.57		43	2.52						
20	1.41		44	1.93						
24	1.8		**45***	**1.86***						
27	1.66		46	1.48						
28	1.58		47	1.21						
29	1.84		48	1.18						
30	2.28		50	0.96						
31	3.04		53	0.68						
33	3.29		57	0.17						
35	3.22		60	0						

Laurel Run

Date of Survey: May 12, 2007 Time of Survey: 12:37 am

Reach #: 19-A Drainage Area: 5.1 sq. miles

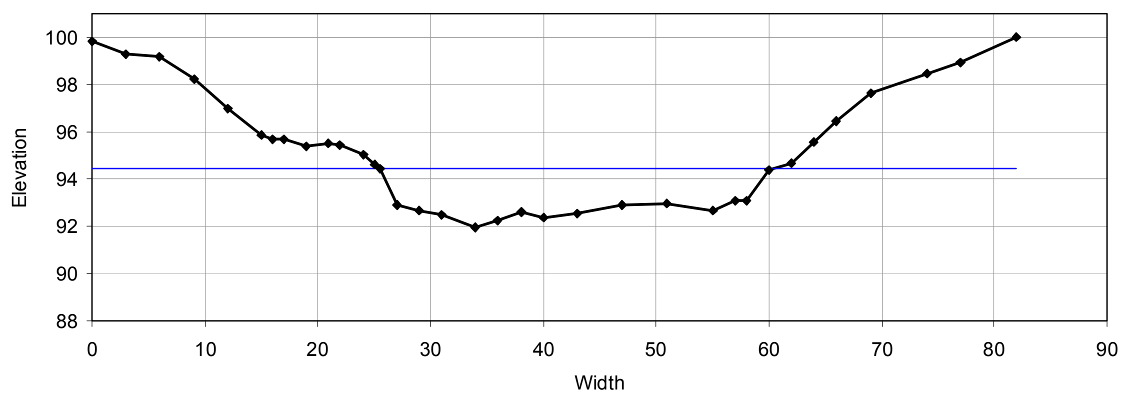
UTM Coordinate Location: Zone 18, 4458794 m N, 0284863 m E

Location Information: Tuscarora State Forest, parked vehicle at intersection of Laurel Run Road and North Fork Trail.

Bankfull Indicator(s): A change in slope along the east channel bank, extrapolated from 30 feet upstream.

Bankfull Response Variables: Cross-sectional area (58.7 square feet), width (35.1 feet), mean depth (1.7 feet)

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.17		27	7.09		62	5.34			
3	0.71		29	7.33		64	4.41			
6	0.86		31	7.51		66	3.53			
9	1.77		34	8.04		69	2.37			
12	3.02		36	7.73		74	1.55			
15	4.15		38	7.39		77	1.08			
16	4.32		40	7.63		82	0			
17	4.29		43	7.44						
19	4.61		47	7.08						
21	4.49		51	7.01						
22	4.54		55	7.31						
24	4.99		57	6.89						
25	5.37		58	6.93						
25.5*	**5.55***		60	5.64						

Laurel Run

Date of Survey: May 12, 2007 Time of Survey: 1:00 pm

Reach #: 19-B Drainage Area: 5.1 sq. miles

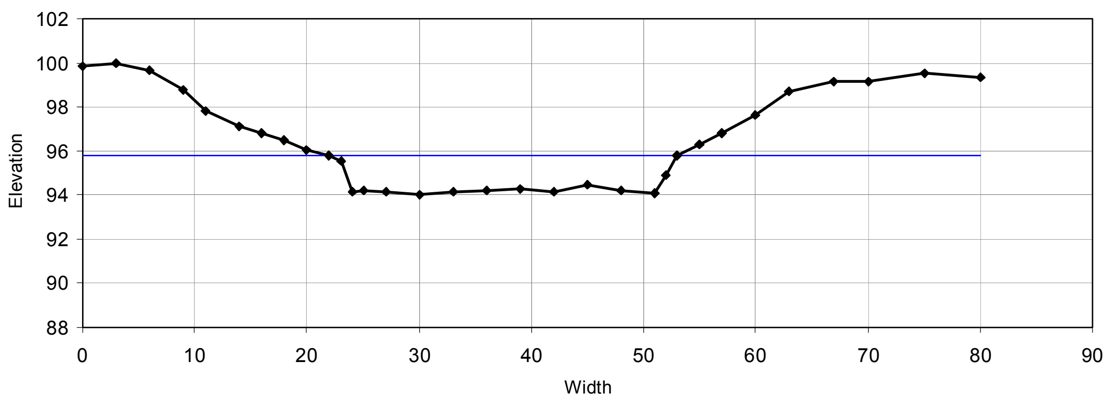
UTM Coordinate Location: Zone 18, 4458793 m N, 0284851 m E

Location Information: Tuscarora State Forest, reach located approximately 100 feet downstream of 19-A.

Bankfull Indicator(s): A change in slope along the east channel bank.

Bankfull Response Variables: Cross-sectional area (46.6 square feet), width (31.2 feet), mean depth (1.5 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.15		30	5.99		67	0.84			
3	0		33	5.83		70	0.86			
6	0.37		36	5.82		75	0.46			
9	1.22		39	5.72		80	0.63			
11	2.16		42	5.86						
14	2.9		45	5.57						
16	3.18		48	5.81						
18	3.48		51	5.89						
20	3.93		52	5.1						
22*	**4.22***		53	4.19						
23	4.47		55	3.69						
24	5.84		57	3.22						
25	5.8		60	2.37						
27	5.84		63	1.27						

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 9:26 am

Reach #: 20-A Drainage Area: 0.76 sq. miles

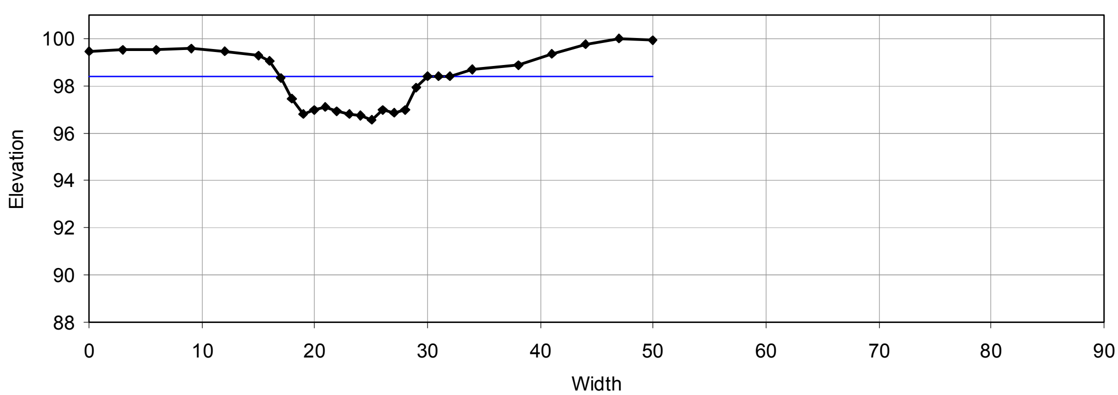
UTM Coordinate Location: Zone 18, 4455295 m N, 0281016 m E

Location Information: Tuscarora State Forest, parked vehicle at intersection of Laurel Run Road and College Trail.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (16.7 square feet), width (13.1 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.53		24	3.23		50	0.08			
3	0.49		25	3.45						
6	0.48		26	3.04						
9	0.43		27	3.11						
12	0.51		28	2.99						
15	0.71		29	2.07						
16	0.97		**30***	**1.6***						
17	1.66		31	1.66						
18	2.55		32	1.59						
19	3.21		34	1.31						
20	3.04		38	1.12						
21	2.91		41	0.64						
22	3.1		44	0.23						
23	3.18		47	0						

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 9:41 am

Reach #: 20-B Drainage Area: 0.76 sq. miles

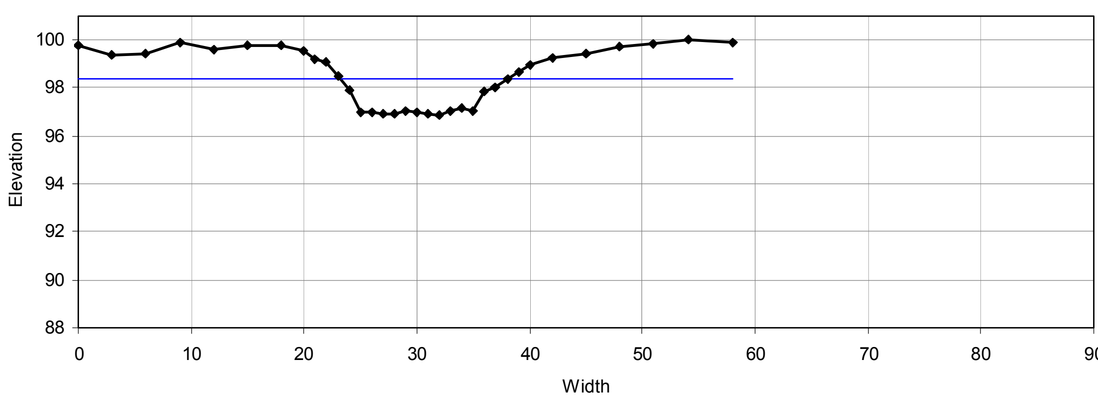
UTM Coordinate Location: Zone 18, 4455305 m N, 0281027 m E

Location Information: Tuscarora State Forest, reach located approximately 100 feet downstream of 20-A.

Bankfull Indicator(s): A change in slope along the northwest channel bank, extrapolated 10 feet upstream.

Bankfull Response Variables: Cross-sectional area (16.7 square feet), width (13.1 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.24		27	3.07		42	0.74			
3	0.66		28	3.09		45	0.55			
6	0.55		29	2.98		48	0.31			
9	0.11		30	3.01		51	0.14			
12	0.38		31	3.06		54	0			
15	0.25		32	3.12		58	0.11			
18	0.2		33	2.94						
20	0.43		34	2.82						
21	0.79		35	2.96						
22	0.93		36	2.15						
23	1.53		37	1.98						
24	2.1		**38***	**1.63***						
25	3.05		39	1.36						
26	3.04		40	1.05						

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 10:42 am

Reach #: 21-A Drainage Area: 2.12 sq. miles

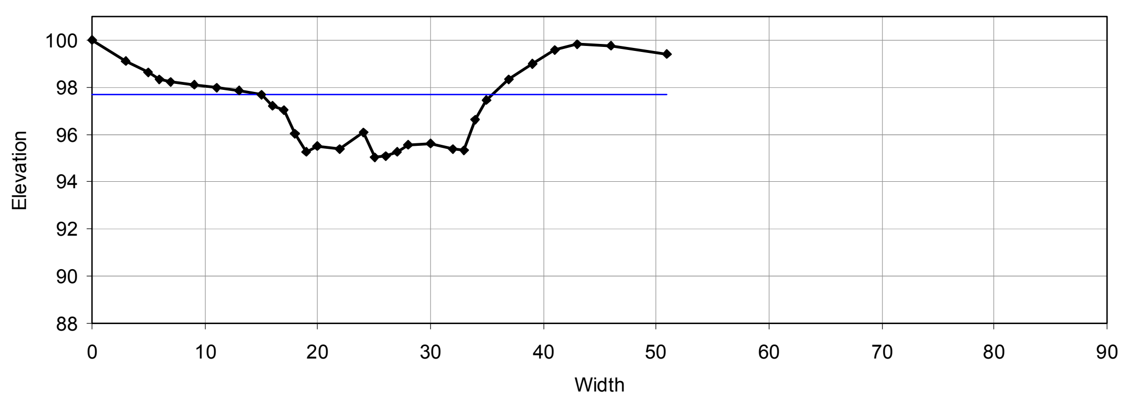
UTM Coordinate Location: Zone 18, 4456154 m N, 0282025 m E

Location Information: Tuscarora State Forest, parked vehicle on Ant Hill Trail.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (37.8 square feet), width (20.6 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		22	4.6		43	0.17			
3	0.92		24	3.89		46	0.24			
5	1.37		25	4.96		51	0.57			
6	1.64		26	4.92						
7	1.75		27	4.74						
9	1.92		28	4.43						
11	2		30	4.35						
13	2.14		32	4.63						
15*	**2.29***		33	4.68						
16	2.78		34	3.36						
17	2.94		35	2.55						
18	3.97		37	1.63						
19	4.71		39	0.99						
20	4.49		41	0.43						

Laurel Run

Date of Survey: May 14, 2007 | Time of Survey: 10:59 am

Reach #: 21-B | Drainage Area: 2.12 sq. miles

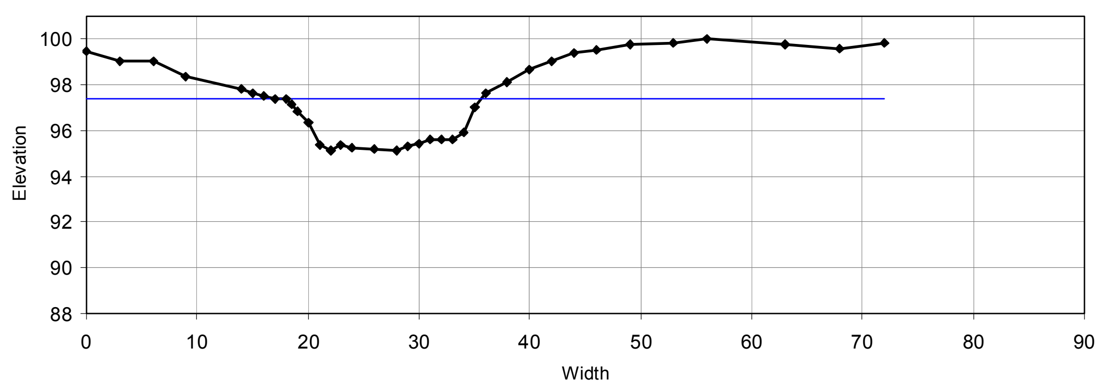
UTM Coordinate Location: Zone 18, 4456176 m N, 0281989 m E

Location Information: Tuscarora State Forest, parked vehicle on Ant Hill Trail. Reach located approximately 100 feet upstream of 21-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (29.6 square feet), width (17.6 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0.55	23	4.62	42	0.93		
3	0.97	24	4.73	44	0.61		
6	0.95	26	4.82	46	0.47		
9	1.61	28	4.87	49	0.21		
14	2.2	29	4.67	53	0.18		
15	2.35	30	4.55	56	0		
16	2.47	31	4.39	63	0.22		
17	2.61	32	4.35	68	0.42		
18	2.62	33	4.37	72	0.15		
18.5*	**2.84***	34	4.06				
19	3.16	35	2.94				
20	3.64	36	2.38				
21	4.63	38	1.84				
22	4.84	40	1.32				

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 12:37 am

Reach #: 22-A Drainage Area: 7.47 sq. miles

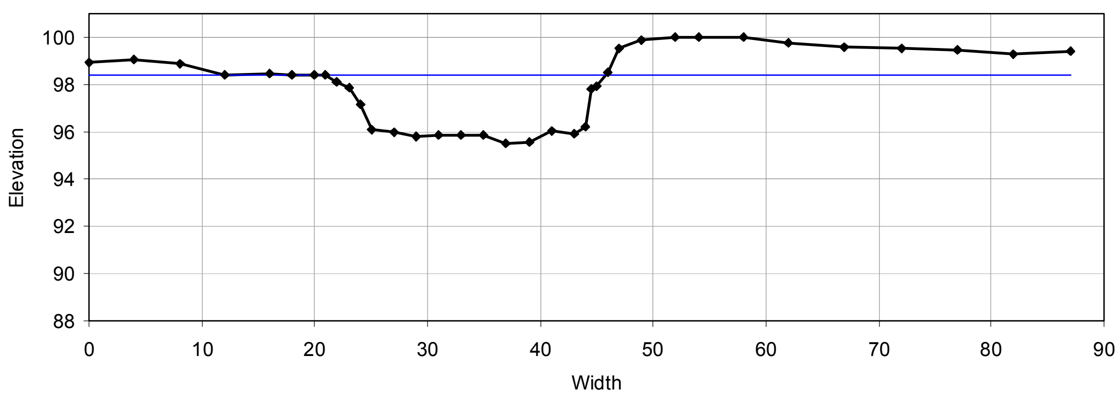
UTM Coordinate Location: Zone 18, 4459957 m N, 0288247 m E

Location Information: Tuscarora State Forest, parked vehicle at the intersection of Laurel Run Road and Meadow Road. Reach located upstream of confluence.

Bankfull Indicator(s): A change in slope along the south to southeast channel bank and change in vegetation from moss (inside channel) to fern (outside channel).

Bankfull Response Variables: Cross-sectional area (52.4 square feet), width (24.7 feet), mean depth (2.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.06		31	4.13		54	0			
4	0.94		33	4.17		58	0.02			
8	1.15		35	4.13		62	0.24			
12	1.6		37	4.47		67	0.42			
16	1.54		39	4.46		72	0.47			
18	1.58		41	3.97		77	0.53			
20	1.59		43	4.06		82	0.74			
21*	**1.62***		44	3.81		87	0.6			
22	1.92		44.5	2.18						
23	2.14		45	2.05						
24	2.86		46	1.46						
25	3.88		47	0.49						
27	4		49	0.1						
29	4.18		52	0.01						

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 1:18 pm

Reach #: 22-B Drainage Area: 7.47 sq. miles

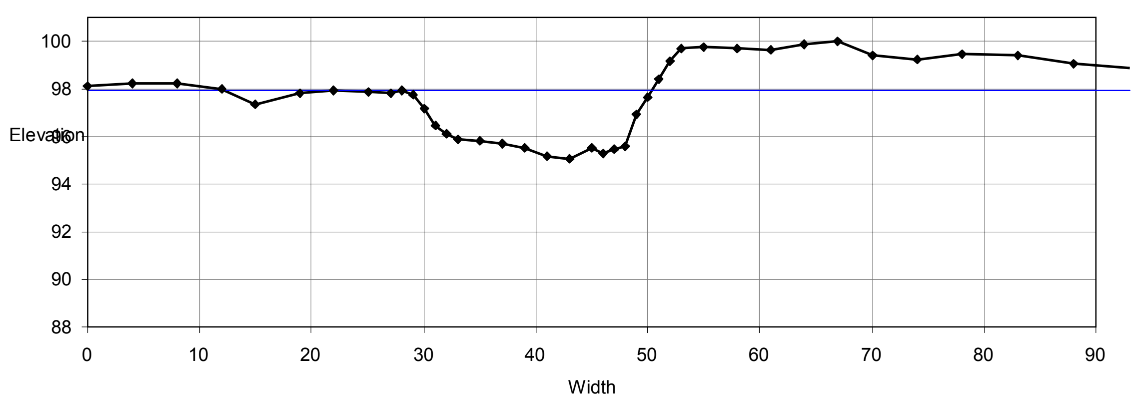
UTM Coordinate Location: Zone 18, 4459949 m N, 0288256 m E

Location Information: Tuscarora State Forest, parked vehicle at the intersection of Laurel Run Road and Meadow Road. Reach located 50 feet downstream of 22-A.

Bankfull Indicator(s): A change in slope along the south to southeast channel bank and change in vegetation from moss (inside channel) to fern (outside channel).

Bankfull Response Variables: Cross-sectional area (45.2 square feet), width (22.4 feet), mean depth (2.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	1.87	33	4.14	53	0.32		
4	1.75	35	4.18	55	0.22		
8	1.79	37	4.31	58	0.3		
12	2.02	39	4.45	61	0.33		
15	2.62	41	4.84	64	0.1		
19	2.2	43	4.94	67	0		
22	2.07	45	4.45	70	0.56		
25	2.11	46	4.7	74	0.78		
27	2.17	47	4.52	78	0.53		
28*	**2.03***	48	4.42	83	0.57		
29	2.25	49	3.07	88	0.92		
30	2.82	50	2.36	93	1.13		
31	3.54	51	1.6				
32	3.91	52	0.82				

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 2:03 pm

Reach #: 23-A Drainage Area: 10.8 sq. miles

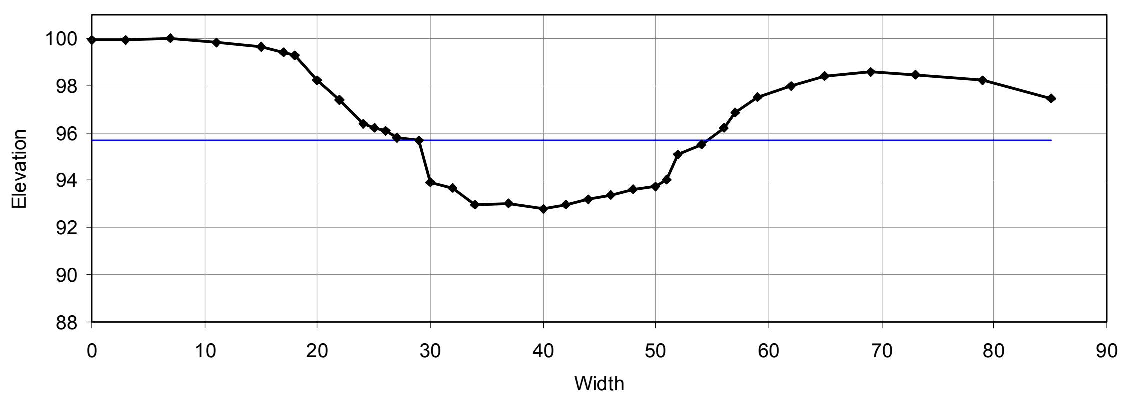
UTM Coordinate Location: Zone 18, 4460026 m N, 0288292 m E

Location Information: Tuscarora State Forest, parked vehicle at the intersection of Laurel Run Road and Meadow Road. Reach located downstream of confluence.

Bankfull Indicator(s): A change in slope along the east channel bank.

Bankfull Response Variables: Cross-sectional area (53.0 square feet), width (25.4 feet), mean depth (2.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.06		30	6.08		57	3.12			
3	0.05		32	6.3		59	2.48			
7	0		34	7.03		62	2			
11	0.16		37	6.99		65	1.6			
15	0.38		40	7.24		69	1.44			
17	0.6		42	7.06		73	1.57			
18	0.73		44	6.82		79	1.8			
20	1.76		46	6.63		85	2.56			
22	2.63		48	6.36						
24	3.59		50	6.26						
25	3.8		51	5.95						
26	3.93		52	4.88						
27	4.18		54	4.5						
29*	**4.34***		56	3.77						

Laurel Run

Date of Survey: May 14, 2007 Time of Survey: 2:25 pm

Reach #: 23-B Drainage Area: 10.8 sq. miles

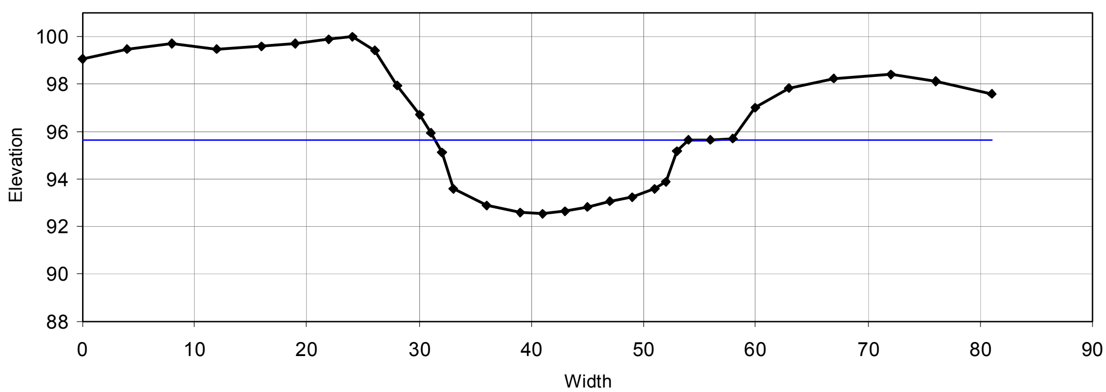
UTM Coordinate Location: Zone 18, 4460052 m N, 0288305 m E

Location Information: Tuscarora State Forest, parked vehicle at the intersection of Laurel Run Road and Meadow Road. Reach located 50 feet downstream of 23-A.

Bankfull Indicator(s): A change in slope along the west to northwest channel bank, consistent with the highest elevation of a point bar in the adjacent upstream riffle.

Bankfull Response Variables: Cross-sectional area (53.2 square feet), width (22.6 feet), mean depth (2.4 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.96		36	7.14		63	2.18			
4	0.53		39	7.4		67	1.76			
8	0.3		41	7.45		72	1.6			
12	0.54		43	7.38		76	1.87			
16	0.43		45	7.16		81	2.39			
19	0.27		47	6.93						
22	0.1		49	6.74						
24	0		51	6.41						
26	0.58		52	6.13						
28	2.07		53	4.82						
30	3.32		**54***	**4.37***						
31	4.07		56	4.46						
32	4.86		58	4.28						
33	6.39		60	2.99						

Laurel Run

Date of Survey: May 15, 2007 Time of Survey: 9:26 am

Reach #: 24-A Drainage Area: 13.9 sq. miles

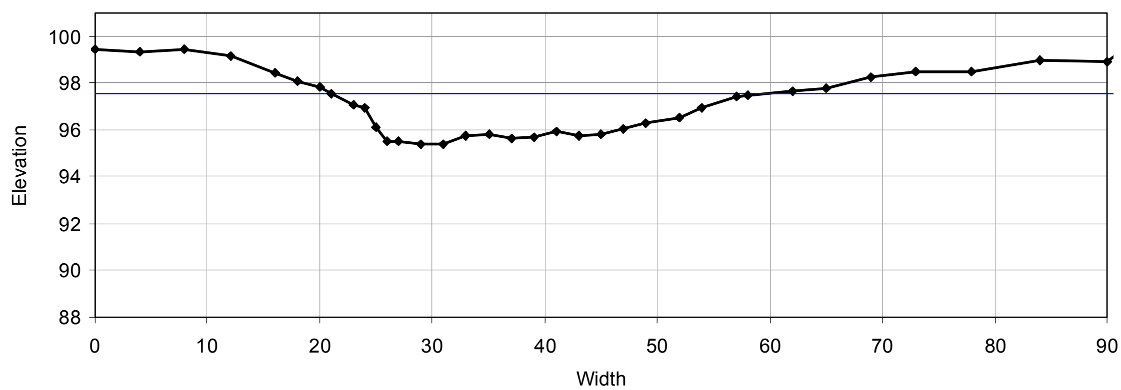
UTM Coordinate Location: Zone 18, 4461110 m N, 0290814 m E

Location Information: Tuscarora State Forest, parked vehicle on Meadow Road at bridge over Laurel Run.

Bankfull Indicator(s): A change in slope along the northwest channel bank.

Bankfull Response Variables: Cross-sectional area (52.0 square feet), width (38.6 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.54		31	4.61		62	2.31			
4	0.65		33	4.27		65	2.24			
8	0.53		35	4.2		69	1.77			
12	0.83		37	4.35		73	1.48			
16	1.57		39	4.31		78	1.49			
18	1.95		41	4.08		84	1			
20	2.14		43	4.25		90	1.09			
21*	**2.45***		45	4.19		93	0			
23	2.91		47	3.94						
24	3.06		49	3.7						
25	3.87		52	3.48						
26	4.47		54	3.05						
27	4.48		57	2.58						
29	4.61		58	2.54						

Laurel Run

Date of Survey: May 15, 2007 Time of Survey: 9:50 am

Reach #: 24-B Drainage Area: 13.9 sq. miles

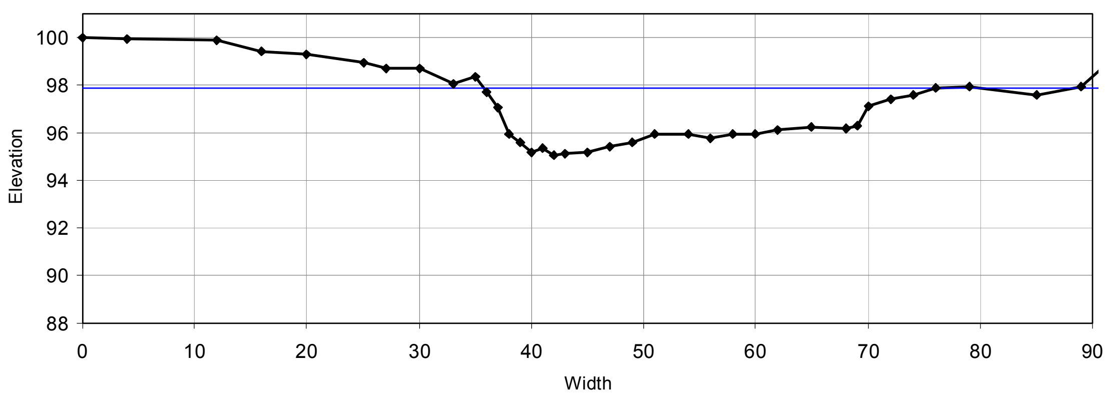
UTM Coordinate Location: Zone 18, 4461174 m N, 0290828 m E

Location Information: Tuscarora State Forest, parked vehicle on Meadow Road at bridge over Laurel Run. Reach located upstream of 24-A approximately 100 feet.

Bankfull Indicator(s): A change in slope along the southeast channel bank.

Bankfull Response Variables: Cross-sectional area (72.1 square feet), width (40.3 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		40	4.81		68	3.84			
4	0.04		41	4.65		69	3.69			
12	0.09		42	4.94		70	2.87			
16	0.58		43	4.9		72	2.61			
20	0.73		45	4.82		74	2.43			
25	1.03		47	4.58		**76***	**2.09***			
27	1.29		49	4.39		79	2.06			
30	1.29		51	4.04		85	2.4			
33	1.92		54	4.03		89	2.03			
35	1.67		56	4.22		91	1.21			
36	2.3		58	4.08		96	0.86			
37	2.92		60	4.04						
38	4.05		62	3.89						
39	4.42		65	3.79						

Conodoguinet Creek

Date of Survey: April 28, 2007 Time of Survey: 10:09 am

Reach #: 25-A Drainage Area: 28.3 sq. miles

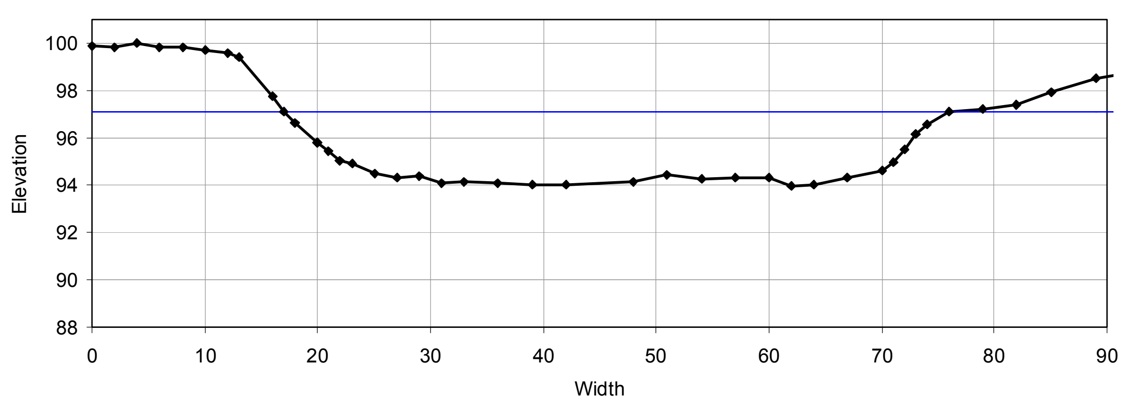
UTM Coordinate Location: Zone 18, 4442243 m N, 0268850 m E

Location Information: Private Property, adjacent to GIS Hunting Club land. Parked vehicle off Horse Valley Road, near cabin with u-shaped driveway.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (150.3 square feet), width (59.1 feet), mean depth (2.5 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.1		23	5.11		62	6.02			
2	0.16		25	5.51		64	5.97			
4	0		27	5.67		67	5.7			
6	0.2		29	5.63		70	5.36			
8	0.16		31	5.89		71	5.05			
10	0.3		33	5.87		72	4.51			
12	0.44		36	5.91		73	3.82			
13	0.61		39	5.96		74	3.44			
16	2.27		42	5.97		**76***	**2.88***			
17	2.92		48	5.83		79	2.8			
18	3.35		51	5.57		82	2.62			
20	4.22		54	5.75		85	2.07			
21	4.57		57	5.68		89	1.47			
22	4.97		60	5.67		95	1			

Conodoguinet Creek

Date of Survey: April 28, 2007 — Time of Survey: 10:51 am

Reach #: 25-B — Drainage Area: 28.3 sq. miles

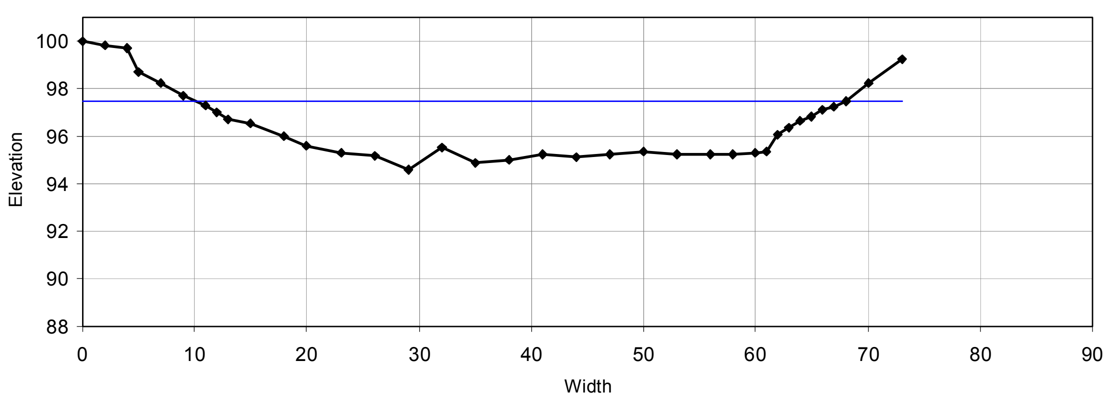
UTM Coordinate Location: Zone 18, 4442218 m N, 0268887 m E

Location Information: Private Property, adjacent to GIS Hunting Club land. Reach located downstream of 25-A.

Bankfull Indicator(s): A change in slope along the south channel bank, highest elevation of point bar is consistent with bankfull stage elevation.

Bankfull Response Variables: Cross-sectional area (110.5 square feet), width (58.0 feet), mean depth (1.9 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		29	5.39		63	3.67			
2	0.16		32	4.49		64	3.38			
4	0.27		35	5.13		65	3.16			
5	1.27		38	5		66	2.91			
7	1.75		41	4.77		67	2.76			
9	2.27		44	4.9		**68***	**2.51***			
11	2.73		47	4.77		70	1.77			
12	2.98		50	4.64		73	0.75			
13	3.27		53	4.78						
15	3.49		56	4.77						
18	4.01		58	4.76						
20	4.39		60	4.72						
23	4.7		61	4.62						
26	4.84		62	3.94						

Conodoguinet Creek

Date of Survey: April 28, 2007 Time of Survey: 12:41 am

Reach #: 26-A Drainage Area: 25.3 sq. miles

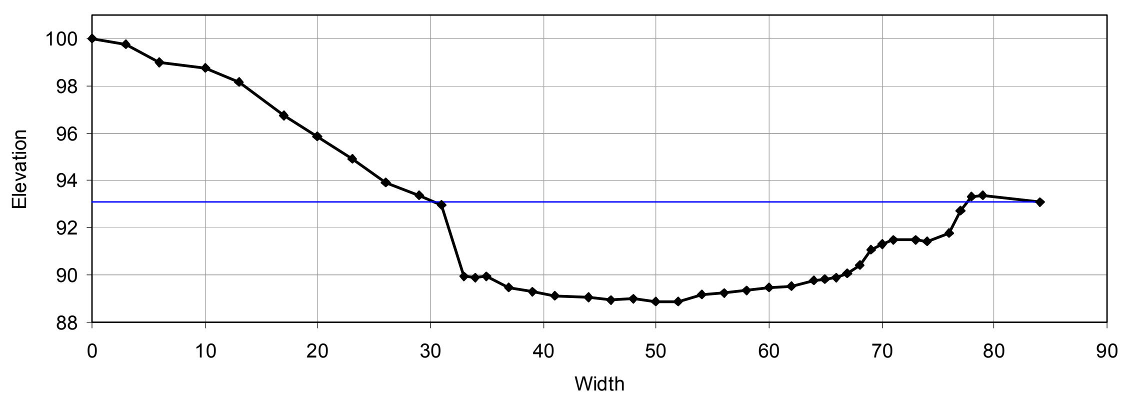
UTM Coordinate Location: Zone 18, 4440697 m N, 0266759 m E

Location Information: Pennsylvania State Game Lands # 76, parked at power line on Horse Valley Road.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (149.1 square feet), width (47.3 feet), mean depth (3.2 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		37	10.55		65	10.15			
3	0.24		39	10.7		66	10.09			
6	1.02		41	10.89		67	9.95			
10	1.24		44	10.94		68	9.59			
13	1.83		46	11.07		69	8.93			
17	3.23		48	11		70	8.69			
20	4.16		50	11.11		71	8.51			
23	5.09		52	11.11		73	8.52			
26	6.1		54	10.79		74	8.55			
29	6.63		56	10.78		76	8.21			
31	7.05		58	10.67		**77***	**7.26***			
33	10.03		60	10.51		78	6.66			
34	10.1		62	10.45		79	6.61			
35	10.03		64	10.24		84	6.89			

Conodoguinet Creek

Date of Survey: April 28, 2007 Time of Survey: 1:33 pm

Reach #: 26-B Drainage Area: 25.3 sq. miles

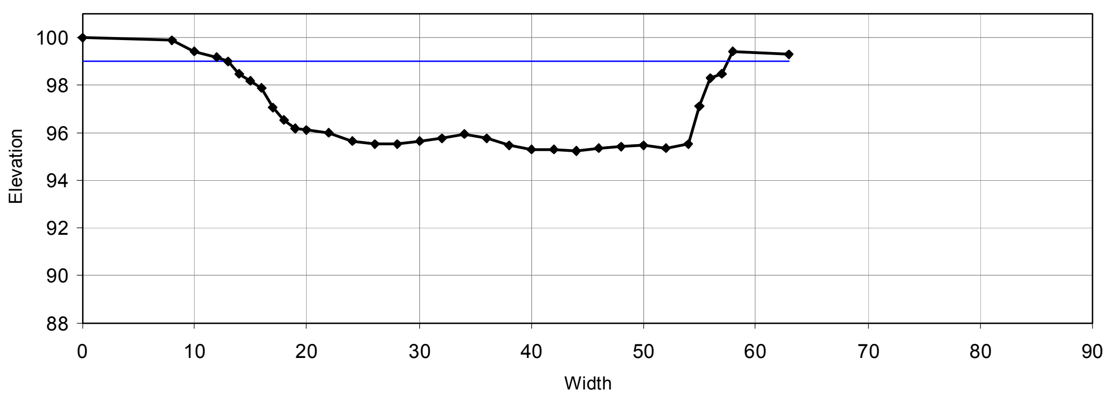
UTM Coordinate Location: Zone 18, 4440721 m N, 0266815 m E

Location Information: Pennsylvania State Game Lands # 76, parked at power line on Horse Valley Road. Reach located downstream of 26-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (131.5 square feet), width (44.5 feet), mean depth (3.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0		26	4.45		54	4.45			
8	0.12		28	4.47		55	2.86			
10	0.58		30	4.35		56	1.69			
12	0.83		32	4.21		57	1.5			
13*	**1.02***		34	4.03		58	0.6			
14	1.53		36	4.21		63	0.69			
15	1.83		38	4.55						
16	2.09		40	4.7						
17	2.96		42	4.73						
18	3.47		44	4.75						
19	3.83		46	4.62						
20	3.88		48	4.57						
22	4.01		50	4.51						
24	4.33		52	4.63						

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 9:43 am

Reach #: 27-A Drainage Area: 20.3 sq. miles

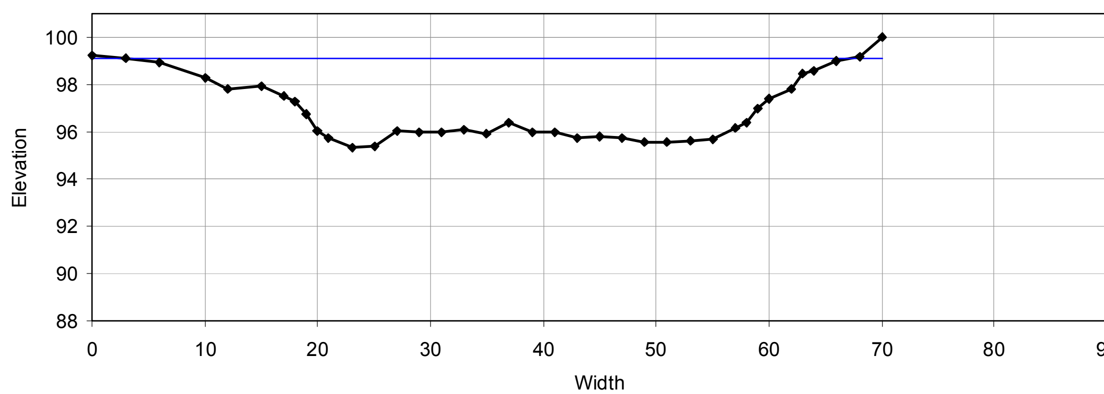
UTM Coordinate Location: Zone 18, 4438715 m N, 0264460 m E

Location Information: Private land with public fishing access, located upstream of sandstone bridge over creek. Reach located at intersection of Upper Strasburg Road and Horse Valley Road.

Bankfull Indicator(s): A change in slope along the north to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (152.0 square feet), width (64.7 feet), mean depth (2.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.76		29	4		57	3.82			
3*	**0.88***		31	4.02		58	3.6			
6	1.08		33	3.93		59	2.99			
10	1.73		35	4.06		60	2.59			
12	2.18		37	3.63		62	2.18			
15	2.08		39	4		63	1.55			
17	2.49		41	4.04		64	1.41			
18	2.75		43	4.23		66	0.99			
19	3.23		45	4.2		68	0.86			
20	3.96		47	4.25		70	0			
21	4.24		49	4.42						
23	4.66		51	4.46						
25	4.6		53	4.36						
27	3.96		55	4.29						

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 10:23 am

Reach #: 27-B Drainage Area: 20.3 sq. miles

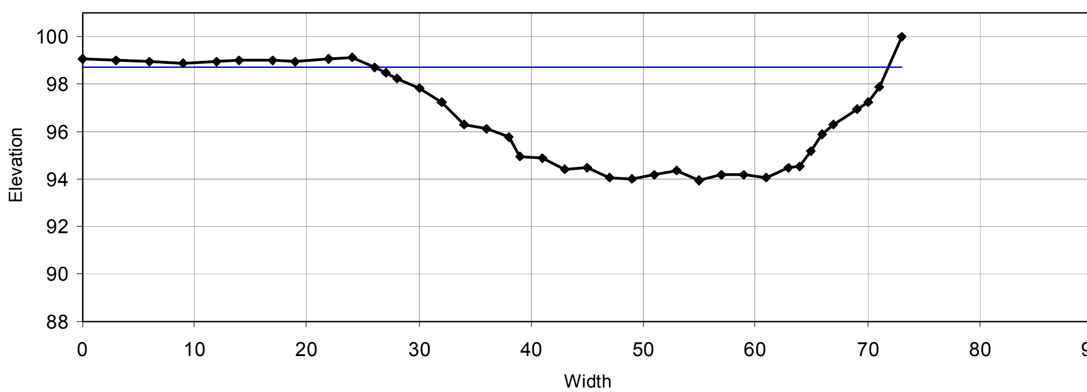
UTM Coordinate Location: Zone 18, 4438731 m N, 0264445 m E

Location Information: Private land with public fishing access, located upstream of sandstone bridge over creek. Reach located downstream of27-A, approximately 150 upstream of bridge.

Bankfull Indicator(s): A change in slope along the north to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (150.1 square feet), width (45.8 feet), mean depth (3.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	0.96	32	2.79	59	5.85		
3	0.98	34	3.69	61	5.94		
6	1.07	36	3.89	63	5.52		
9	1.12	38	4.25	64	5.45		
12	1.04	39	5.05	65	4.81		
14	1.01	41	5.1	66	4.09		
17	1	43	5.58	67	3.72		
19	1.06	45	5.5	69	3.05		
22	0.93	47	5.93	70	2.75		
24	0.91	49	5.99	71	2.11		
26*	**1.27***	51	5.81	73	0		
27	1.51	53	5.64				
28	1.79	55	6.03				
30	2.16	57	5.85				

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 11:39 am

Reach #: 28-A Drainage Area: 16.1 sq. miles

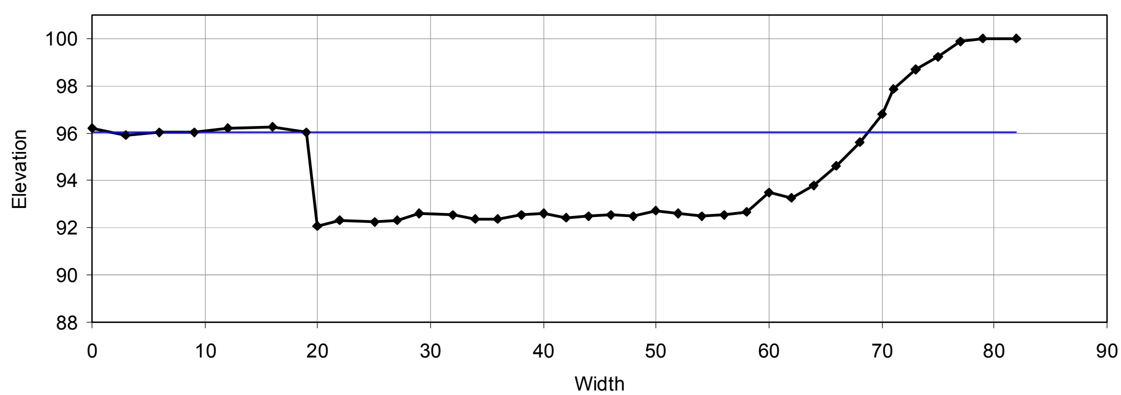
UTM Coordinate Location: Zone 18, 4436834 m N, 0261706 m E

Location Information: Private land with public fishing access, located on Keefer Road at the bridge over the creek.

Bankfull Indicator(s): A change in slope along the north to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (159.1 square feet), width (49.7 feet), mean depth (3.2 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	3.77		36	7.6		64	6.23			
3	4.1		38	7.47		66	5.39			
6	3.99		40	7.4		68	4.35			
9	3.98		42	7.55		70	3.18			
12	3.77		44	7.53		71	2.12			
16	3.7		46	7.43		73	1.29			
19*	**3.96***		48	7.53		75	0.8			
20	7.95		50	7.28		77	0.15			
22	7.68		52	7.38		79	0.02			
25	7.77		54	7.52		82	0			
27	7.68		56	7.45						
29	7.37		58	7.31						
32	7.44		60	6.49						
34	7.6		62	6.73						

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 12:11 am

Reach #: 28-B Drainage Area: 16.1 sq. miles

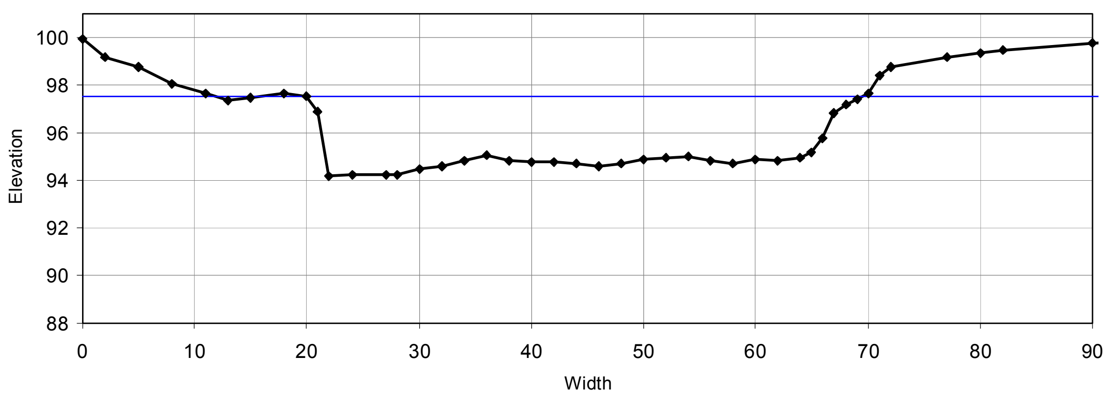
UTM Coordinate Location: Zone 18, 4436899 m N, 0261738 m E

Location Information: Private land with public fishing access, located on Keefer Road at the bridge over the creek. Reach located downstream of 28-A.

Bankfull Indicator(s): A change in slope along the north to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (128.8 square feet), width (49.5 feet), mean depth (2.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.06		30	5.52		58	5.28		82	0.5
2	0.8		32	5.43		60	5.12		90	0.24
5	1.26		34	5.16		62	5.19		100	0
8	1.92		36	4.96		64	5.07			
11	2.33		38	5.15		65	4.83			
13	2.65		40	5.24		66	4.24			
15	2.55		42	5.22		67	3.15			
18	2.35		44	5.29		68	2.82			
20*	**2.45***		46	5.39		69	2.56			
21	3.12		48	5.3		70	2.33			
22	5.8		50	5.1		71	1.6			
24	5.79		52	5.08		72	1.24			
27	5.78		54	5		77	0.8			
28	5.74		56	5.17		80	0.65			

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 1:56 pm

Reach #: 29-A Drainage Area: 4.69 sq. miles

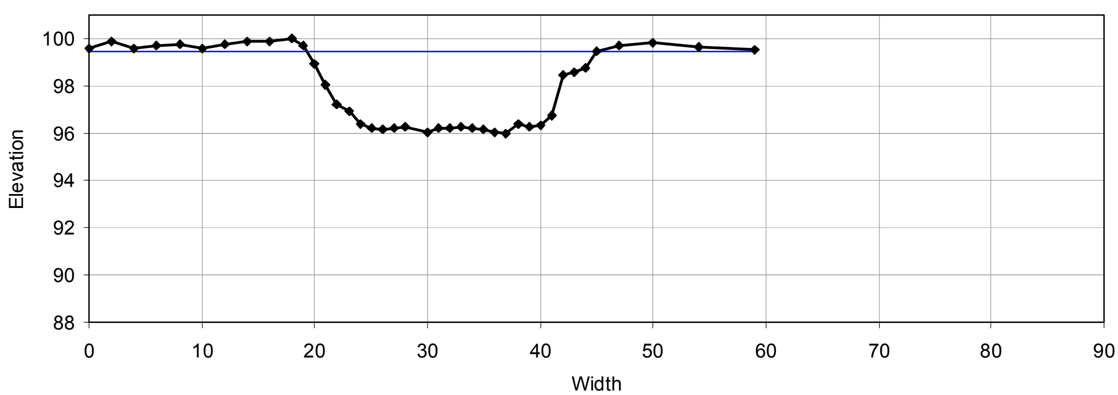
UTM Coordinate Location: Zone 18, 4430466 m N, 0256799 m E

Location Information: Pennsylvania State Game Lands # 235, located at the end of Upper Horse Valley Road.

Bankfull Indicator(s): A change in slope along the east to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (67.9 square feet), width (25.7 feet), mean depth (2.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.41		23	3.05		38	3.61			
2	0.14		24	3.58		39	3.72			
4	0.4		25	3.8		40	3.69			
6	0.32		26	3.85		41	3.24			
8	0.25		27	3.81		42	1.55			
10	0.42		28	3.75		43	1.4			
12	0.27		30	3.94		44	1.23			
14	0.11		31	3.76		**45***	**0.51***			
16	0.11		32	3.81		47	0.28			
18	0		33	3.71		50	0.21			
19	0.31		34	3.77		54	0.33			
20	1.05		35	3.86		59	0.49			
21	1.93		36	3.97		63	0.51			
22	2.78		37	4		67	0.6			

Conodoguinet Creek

Date of Survey: April 29, 2007 Time of Survey: 2:26 pm

Reach #: 29-B Drainage Area: 4.69 sq. miles

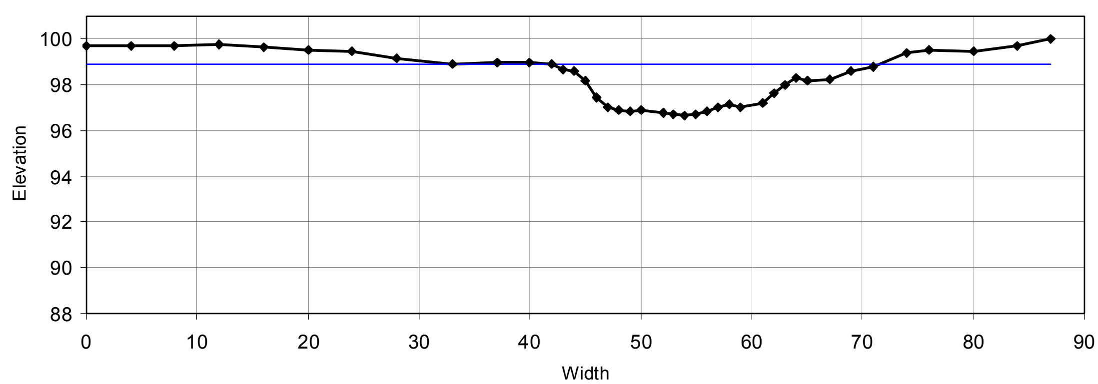
UTM Coordinate Location: Zone 18, 4430391 m N, 0256741 m E

Location Information: Pennsylvania State Game Lands # 235, located at the end of Upper Horse Valley Road. Reach located upstream of 29-A.

Bankfull Indicator(s): A change in slope along the north to northwest channel bank.

Bankfull Response Variables: Cross-sectional area (38.2 square feet), width (29.6 feet), mean depth (1.3 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.27		45	1.78		61	2.8			
4	0.29		46	2.54		62	2.33			
8	0.26		47	2.98		63	2.02			
12	0.24		48	3.06		64	1.71			
16	0.32		49	3.14		65	1.83			
20	0.49		50	3.06		67	1.76			
24	0.54		52	3.23		69	1.41			
28	0.81		53	3.28		71	1.22			
33	1.05		54	3.36		74	0.59			
37	1.02		55	3.3		76	0.49			
40	1.02		56	3.18		80	0.51			
42*	**1.1***		57	2.98		84	0.27			
43	1.31		58	2.82		87	0			
44	1.38		59	2.96						

West Licking Creek

Date of Survey: May 18, 2007 Time of Survey: 1:09 pm

Reach #: 30-A Drainage Area: 1.66 sq. miles

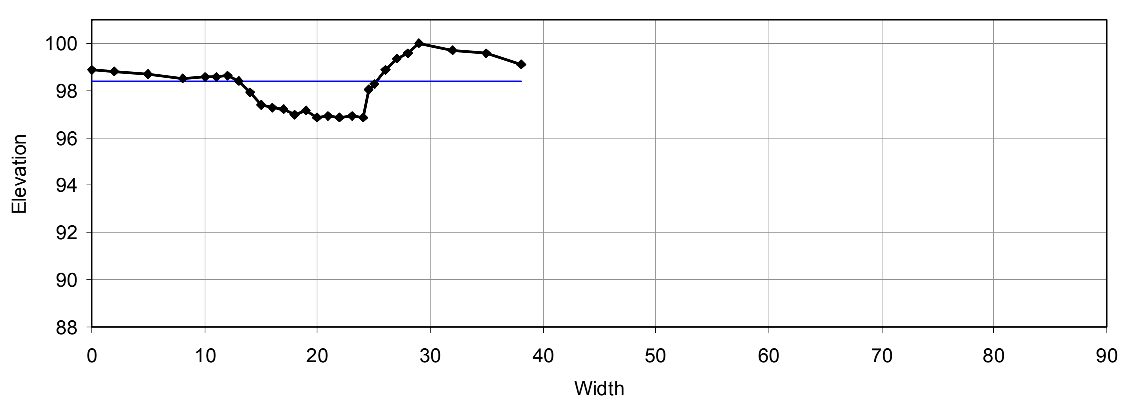
UTM Coordinate Location: Zone 18, 4477248 m N, 0268316 m E

Location Information: Tuscarora State Forest, parked vehicle along Licking Creek Drive near campsite # 17.

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area (13.6 square feet), width (12.2 feet), mean depth (1.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.13		20	3.11						
2	1.21		21	3.07						
5	1.28		22	3.14						
8	1.49		23	3.05						
10	1.42		24	3.14						
11	1.45		24.5	1.98						
12	1.37		25	1.71						
13*	**1.62***		26	1.13						
14	2.1		27	0.68						
15	2.6		28	0.39						
16	2.74		29	0						
17	2.81		32	0.28						
18	3.04		35	0.43						
19	2.82		38	0.92						

West Licking Creek

Date of Survey: May 18, 2007 | Time of Survey: 1:23 pm

Reach #: 30-B | Drainage Area: 1.66 sq. miles

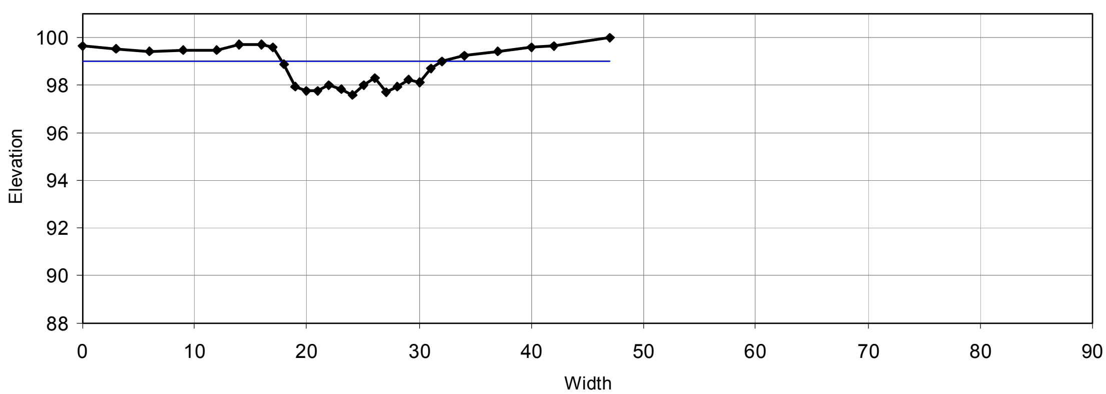
UTM Coordinate Location: Zone 18, 4477243 m N, 0268316 m E

Location Information: Tuscarora State Forest, parked vehicle along Licking Creek Drive near campsite # 17. Reach located approximately 150 feet upstream of 30-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (13.0 square feet), width (14.2 feet), mean depth (0.9 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.38		24	2.41						
3	0.46		25	2.02						
6	0.58		26	1.71						
9	0.54		27	2.29						
12	0.53		28	2.07						
14	0.31		29	1.77						
16	0.28		30	1.86						
17	0.41		31	1.32						
18	1.14		**32***	**1.02***						
19	2.05		34	0.78						
20	2.25		37	0.6						
21	2.26		40	0.42						
22	2.02		42	0.35						
23	2.18		47	0						

West Licking Creek

Date of Survey: May 18, 2007 | Time of Survey: 2:10 pm

Reach #: 31-A | Drainage Area: 2.69 sq. miles

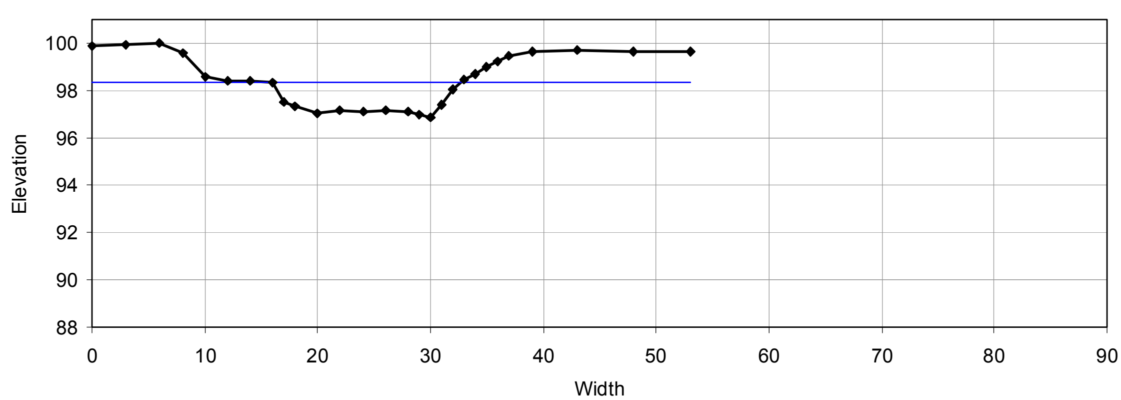
UTM Coordinate Location: Zone 18, 4476066 m N, 0267300 m E

Location Information: Tuscarora State Forest, parked vehicle along an un-named service road off Licking Creek Drive.

Bankfull Indicator(s): A change in slope along the east to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (18.5 square feet), width (16.8 feet), mean depth (1.1 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.15		28	2.88						
3	0.05		29	3.03						
6	0		30	3.13						
8	0.44		31	2.61						
10	1.4		32	1.93						
12	1.66		**33***	**1.56***						
14	1.79		34	1.33						
16	1.63		35	1						
17	2.5		36	0.79						
18	2.67		37	0.55						
20	2.94		39	0.33						
22	2.83		43	0.3						
24	2.92		48	0.37						
26	2.85		53	0.34						

West Licking Creek

Date of Survey: May 18, 2007 Time of Survey: 2:30 pm

Reach #: 31-B Drainage Area: 2.69 sq. miles

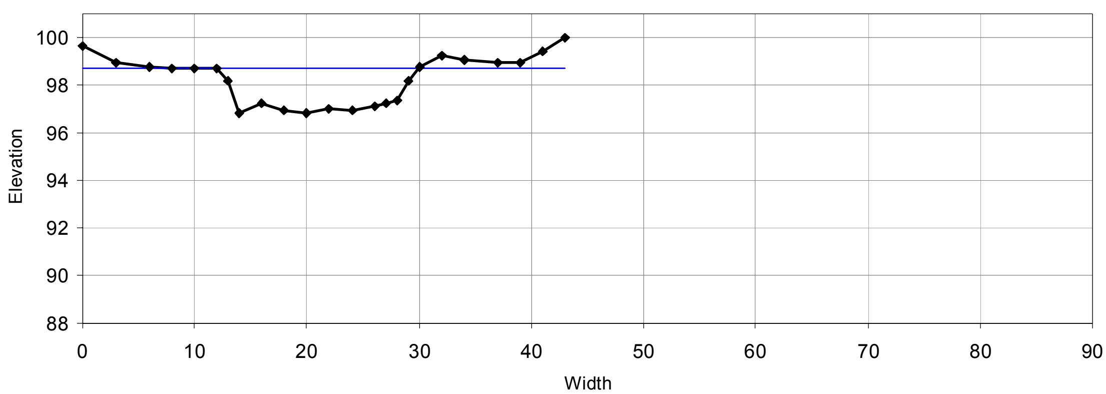
UTM Coordinate Location: Zone 18, 4476114 m N, 0267321 m E

Location Information: Tuscarora State Forest, parked vehicle along an un-named service road off Licking Creek Drive. Reach located approximately 150 feet upstream of 31-A.

Bankfull Indicator(s): A change in slope along the west to southwest channel bank.

Bankfull Response Variables: Cross-sectional area (26.2 square feet), width (18.8 feet), mean depth (1.4 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.37		27	2.77						
3	1.03		28	2.66						
6	1.22		29	1.85						
8	1.31		30	1.23						
10	1.28		32	0.77						
12*	**1.3***		34	0.93						
13	1.8		37	1.03						
14	3.2		39	1.07						
16	2.78		41	0.61						
18	3.04		43	0						
20	3.18									
22	2.98									
24	3.08									
26	2.88									

West Licking Creek

Date of Survey: May 18, 2007 Time of Survey: 4:18 pm

Reach #: 32-A Drainage Area: 6:15 sq. miles

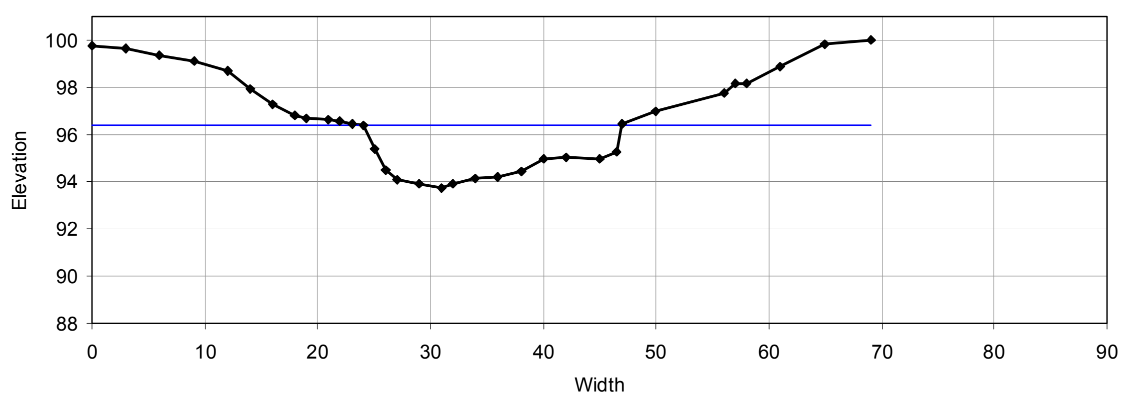
UTM Coordinate Location: Zone 18, 4472487 m N, 0264406 m E

Location Information: Tuscarora State Forest, parked vehicle on Licking Creek Drive.

Bankfull Indicator(s): A change in slope along the north channel bank.

Bankfull Response Variables: Cross-sectional area (41.9 square feet), width (23.0 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.22		26	5.49		56	2.25			
3	0.35		27	5.92		57	1.84			
6	0.63		29	6.07		58	1.84			
9	0.88		31	6.28		61	1.1			
12	1.32		32	6.09		65	0.2			
14	2.06		34	5.87		69	0			
16	2.72		36	5.82						
18	3.19		38	5.55						
19	3.31		40	5.01						
21	3.35		42	4.99						
22	3.41		45	5.01						
23	3.53		46.5	4.73						
24*	**3.63***		47	3.57						
25	4.6		50	2.99						

West Licking Creek

Date of Survey: May 18, 2007 Time of Survey: 4:32 pm

Reach #: 32-B Drainage Area: 6:15 sq. miles

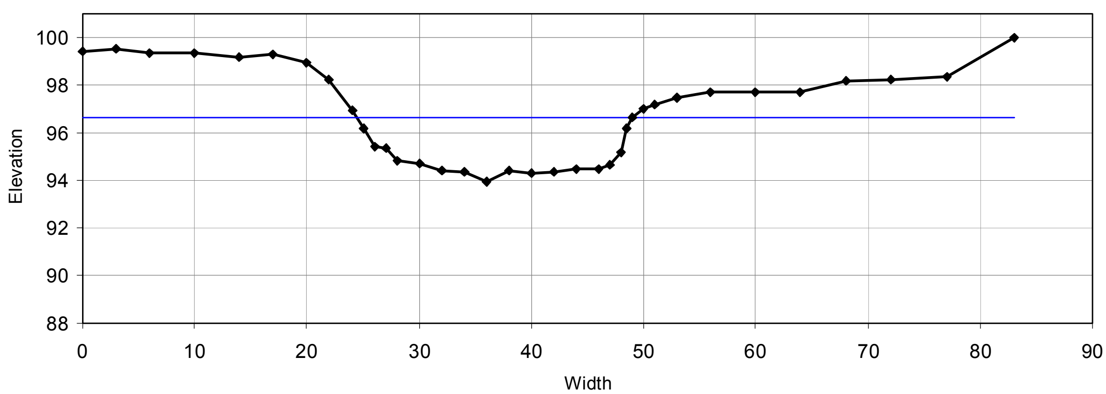
UTM Coordinate Location: Zone 18, 4472488 m N, 0264386 m E

Location Information: Tuscarora State Forest, parked vehicle on Licking Creek Drive. Reach located downstream of 32-A.

Bankfull Indicator(s): A change in slope along the south channel bank.

Bankfull Response Variables: Cross-sectional area (48.8 square feet), width (24.6 feet), mean depth (2.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	0.6		32	5.59		53	2.51			
3	0.48		34	5.67		56	2.28			
6	0.67		36	6.03		60	2.31			
10	0.65		38	5.61		64	2.29			
14	0.8		40	5.69		68	1.83			
17	0.69		42	5.63		72	1.78			
20	1.07		44	5.52		77	1.63			
22	1.78		46	5.55		83	0			
24	3.04		47	5.38						
25	3.81		48	4.85						
26	4.58		48.5	3.83						
27	4.64		**49***	**3.35***						
28	5.19		50	3.01						
30	5.28		51	2.84						

West Licking Creek

Date of Survey: May 19, 2007 Time of Survey: 10:05 am

Reach #: 33-A Drainage Area: 7.46 sq. miles

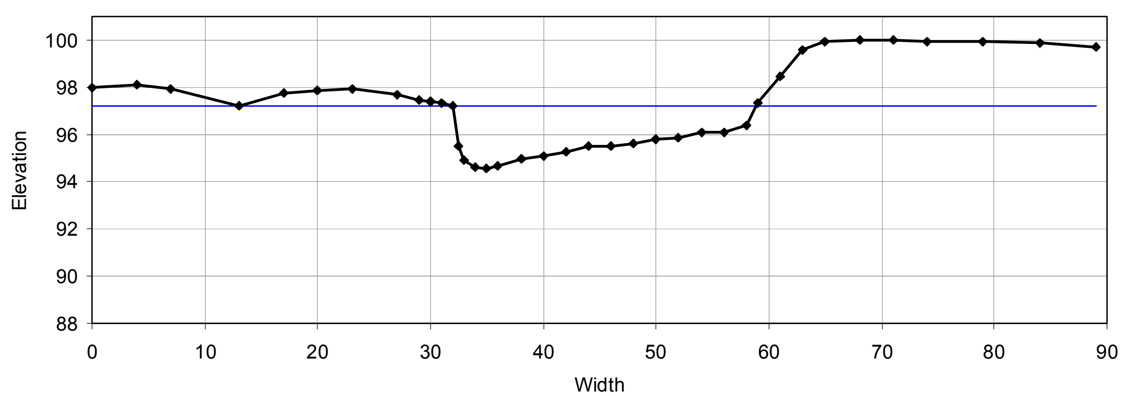
UTM Coordinate Location: Zone 18, 4471458 m N, 0263238 m E

Location Information: Tuscarora State Forest, parked vehicle on Licking Creek Drive.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (45.5 square feet), width (26.9 feet), mean depth (1.7 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	2.04	34	5.41	59	2.68		
4	1.87	35	5.43	61	1.53		
7	2.06	36	5.35	63	0.42		
13	2.81	38	5.04	65	0.04		
17	2.27	40	4.93	68	0.03		
20	2.14	42	4.71	71	0		
23	2.08	44	4.49	74	0.06		
27	2.31	46	4.47	79	0.08		
29	2.55	48	4.39	84	0.13		
30	2.61	50	4.19	89	0.32		
31	2.68	52	4.16				
32*	**2.79***	54	3.93				
32.5	4.47	56	3.92				
33	5.11	58	3.59				

West Licking Creek

Date of Survey: May 19, 2007 Time of Survey: 10:19 am

Reach #: 33-B Drainage Area: 7.46 sq. miles

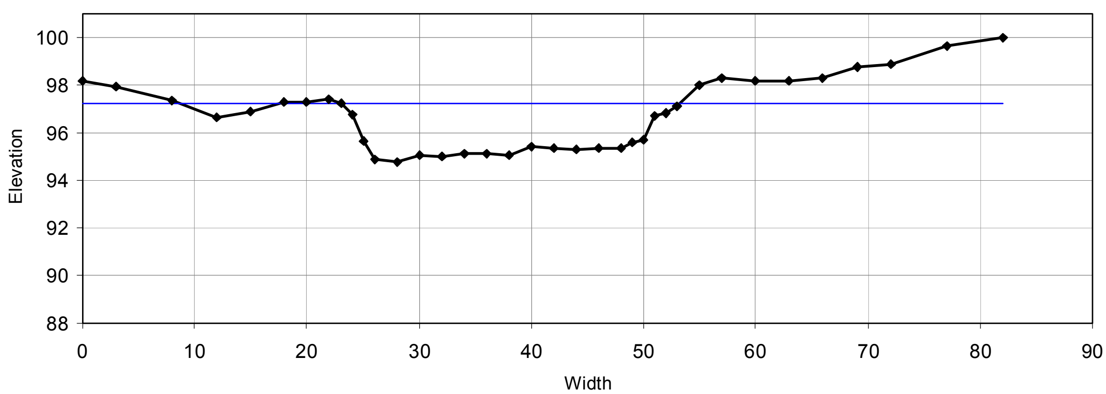
UTM Coordinate Location: Zone 18, 4471472 m N, 0263238 m E

Location Information: Tuscarora State Forest, parked vehicle on Licking Creek Drive. Reach located approximately 100 feet upstream of 33-A.

Bankfull Indicator(s): A change in slope along the west channel bank.

Bankfull Response Variables: Cross-sectional area (54.8 square feet), width (30.3 feet), mean depth (1.8 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	1.8		32	5.02		55	2			
3	2.07		34	4.87		57	1.71			
8	2.63		36	4.87		60	1.8			
12	3.34		38	4.94		63	1.84			
15	3.13		40	4.59		66	1.72			
18	2.71		42	4.65		69	1.24			
20	2.69		44	4.71		72	1.13			
22	2.56		46	4.64		77	0.36			
23*	**2.75***		48	4.66		82	0			
24	3.22		49	4.44						
25	4.34		50	4.31						
26	5.11		51	3.29						
28	5.26		52	3.2						
30	4.94		53	2.88						

West Licking Creek

Date of Survey: May 19, 2007 Time of Survey: 11:43 am

Reach #: 34-A Drainage Area: 10.1 sq. miles

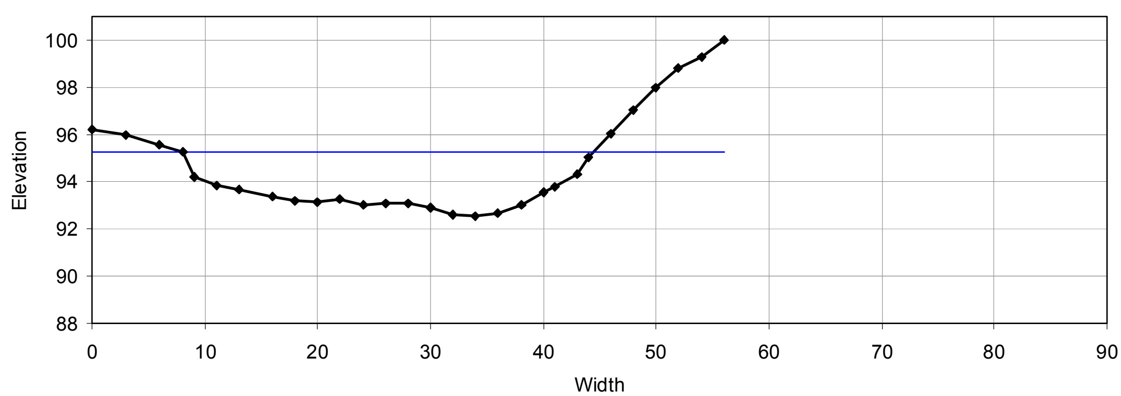
UTM Coordinate Location: Zone 18, 4469927 m N, 0260738 m E

Location Information: Tuscarora State Forest, parked vehicle on Black Log Road.

Bankfull Indicator(s): A change in slope along the east to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (71.3 square feet), width (26.5 feet), mean depth (2.0 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)	Horizontal (feet)	Vertical (feet)
0	3.77	30	7.12	56	0		
3	4.01	32	7.4				
6	4.45	34	7.45				
8*	**4.71***	36	7.36				
9	5.77	38	6.96				
11	6.16	40	6.45				
13	6.32	41	6.23				
16	6.64	43	5.69				
18	6.82	44	4.99				
20	6.87	46	3.95				
22	6.77	48	2.96				
24	6.96	50	2.02				
26	6.89	52	1.16				
28	6.91	54	0.7				

West Licking Creek

Date of Survey: May 19, 2007 Time of Survey: 11:57 am

Reach #: 34-B Drainage Area: 10.1 sq. miles

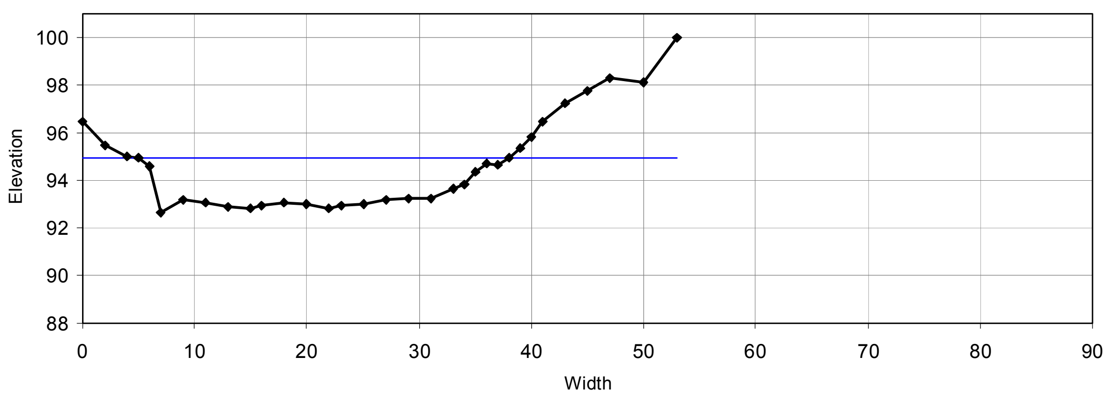
UTM Coordinate Location: Zone 18, 4469916 m N, 0260751 m E

Location Information: Tuscarora State Forest, parked vehicle on Black Log Road. Reach located approximately 150 feet upstream of 34-A.

Bankfull Indicator(s): A change in slope along the east to southeast channel bank.

Bankfull Response Variables: Cross-sectional area (52.9 square feet), width (32.9 feet), mean depth (1.6 feet).

Graph of Channel Cross-Section



Survey Data

Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)		Horizontal (feet)	Vertical (feet)
0	3.51		23	7.07		43	2.75			
2	4.55		25	7		45	2.21			
4	5.02		27	6.82		47	1.71			
5*	**5.08***		29	6.75		50	1.91			
6	5.44		31	6.76		53	0			
7	7.37		33	6.34						
9	6.84		34	6.15						
11	6.97		35	5.67						
13	7.1		36	5.29						
15	7.16		37	5.34						
16	7.08		38	5.05						
18	6.94		39	4.67						
20	6.98		40	4.2						
22	7.16		41	3.52						

Appendix 2. Riffle bedload sediment characteristics in lithologically controlled watersheds.

Bedload pebble-counts data are shown below, along with brief descriptions of bedload sediments, including the dominant lithology in the measured riffle and the dominant clast geometry. Cumulative frequency distribution data for each riffle were used to calculate mean particle size (D50) and mean particle size plus one standard deviation (D84).

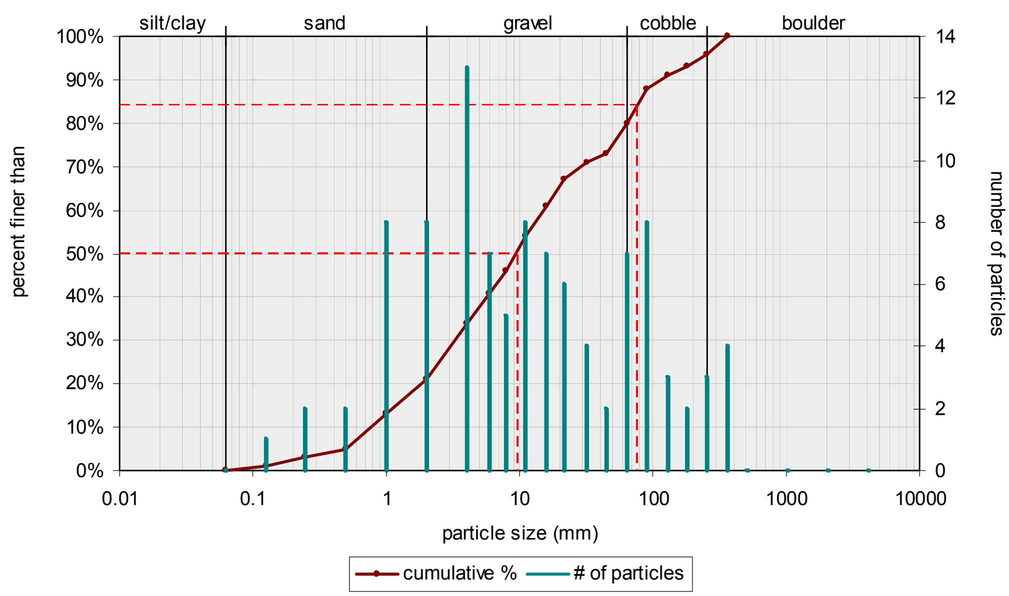
South Branch Little Aughwick Creek

Reach #: 1 UTM Location: Zone 18, 4425800 m N, 0247461 m E

Composition of Bedload: Consists largely of sub-rounded clasts of sandstone and sand grains. Sandstone is very clean, likely a quartz arenite.

Bedload Textures: D50 = 9.0 mm, D84 = 76.0 mm

Cumulative Frequency Distribution



Pebble Count Data

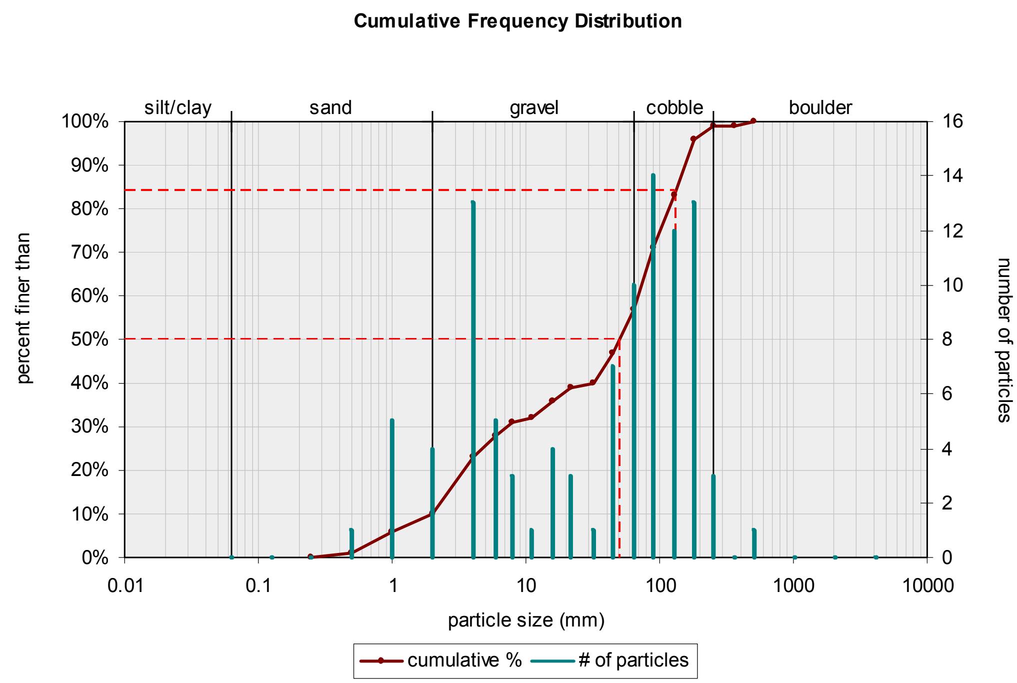
#	Texture		#	Texture		#	Texture		#	Texture		#	Texture		#	Texture
1	6		*18*	65		*35*	5		*52*	0.5		*69*	8		*86*	1
2	16		*19*	320		*36*	13		*53*	87		*70*	5		*87*	194
3	9		*20*	1		*37*	0.125		*54*	0.5		*71*	11		*88*	8
4	9		*21*	65		*38*	58		*55*	27		*72*	2		*89*	0.5
5	3		*22*	11		*39*	73		*56*	78		*73*	1		*90*	0.5
6	0.062		*23*	2		*40*	1		*57*	1		*74*	14		*91*	0.25
7	4		*24*	3		*41*	143		*58*	73		*75*	20		*92*	1
8	2		*25*	9		*42*	143		*59*	63		*76*	10		*93*	37
9	74		*26*	0.5		*43*	47		*60*	190		*77*	6		*94*	25
10	63		*27*	101		*44*	3		*61*	8		*78*	5		*95*	23
11	20		*28*	98		*45*	2		*62*	15		*79*	3		*96*	210
12	37		*29*	2		*46*	3		*63*	0.5		*80*	0.5		*97*	310
13	62		*30*	320		*47*	1		*64*	23		*81*	73		*98*	350
14	7		*31*	122		*48*	0.5		*65*	4		*82*	13		*99*	3
15	17		*32*	16		*49*	0.125		*66*	9		*83*	5		*100*	2
16	54		*33*	1		*50*	0.25		*67*	13		*84*	6			
17	54		*34*	6		*51*	5		*68*	16		*85*	2			

South Branch Little Aughwick Creek

Reach #: 2 UTM Location: Zone 18, 4427256 m N, 0247978 m E

Composition of Bedload: Consists largely of sub-rounded clasts of quartz sandstone, point bar composed of sand grains developing in riffle.

Bedload Textures: D50 = 50.0 mm, D84 = 130.0 mm



Pebble Count Data

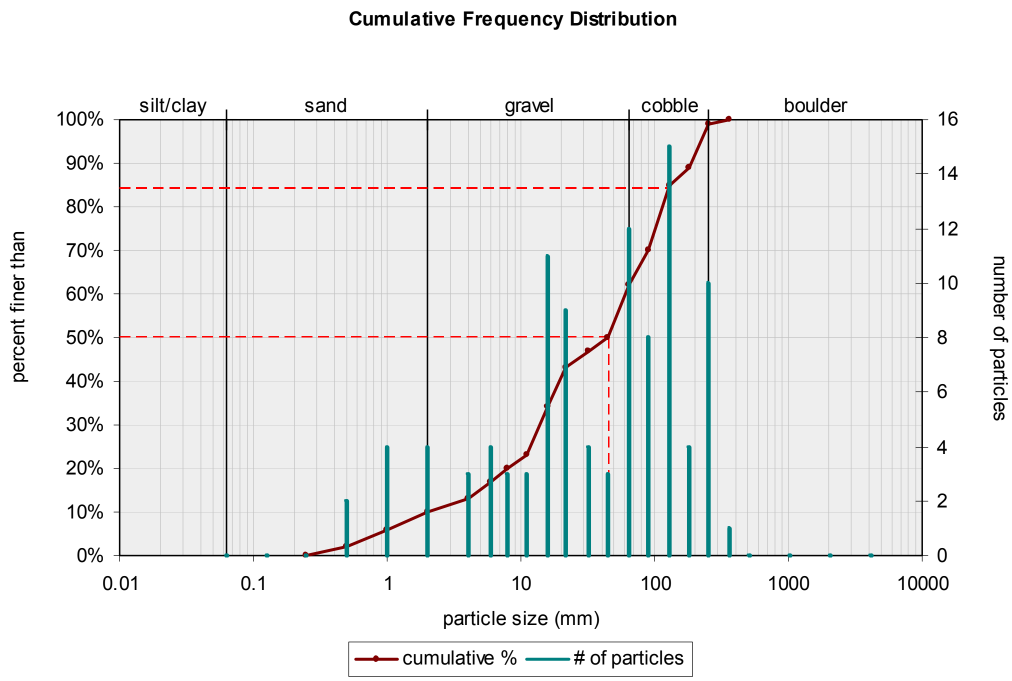
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	142	18	93	35	430	52	2	69	141	86	71
2	81	19	2	36	86	53	70	70	172	87	233
3	6	20	127	37	2	54	123	71	61	88	47
4	2	21	61	38	145	55	128	72	57	89	161
5	11	22	112	39	110	56	130	73	6	90	5
6	33	23	66	40	127	57	2	74	3	91	90
7	0.5	24	145	41	97	58	1	75	1	92	4
8	0.25	25	79	42	49	59	3	76	46	93	12
9	0.5	26	2	43	34	60	4	77	86	94	13
10	0.5	27	39	44	4	61	79	78	181	95	190
11	133	28	17	45	7	62	5	79	83	96	137
12	2	29	2	46	36	63	67	80	1	97	19
13	3	30	39	47	11	64	0.5	81	0.5	98	2
14	146	31	66	48	88	65	52	82	1	99	59
15	46	32	115	49	9	66	2	83	64	100	33
16	16	33	130	50	52	67	155	84	83		
17	102	34	117	51	99	68	27	85	40		

South Branch Little Aughwick Creek

Reach #: 3 UTM Location: Zone 18, 4429065 m N, 0248752 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 45.0 mm, D84 = 130.0 mm



Pebble Count Data

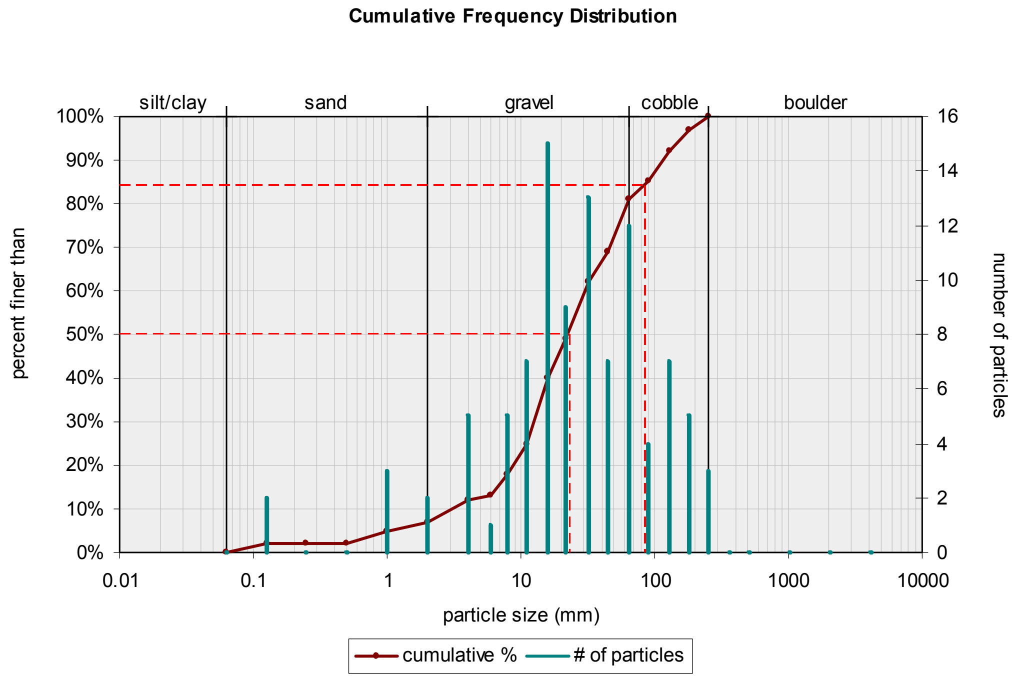
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	1	18	54	35	116	52	13	69	11	86	21
2	110	19	107	36	2	53	12	70	111	87	225
3	72	20	0.5	37	14	54	199	71	116	88	54
4	7	21	77	38	46	55	0.5	72	47	89	20
5	4	22	92	39	5	56	63	73	78	90	76
6	14	23	192	40	49	57	13	74	9	91	171
7	24	24	122	41	91	58	5	75	7	92	80
8	11	25	6	42	1	59	29	76	208	93	114
9	46	26	17	43	1	60	17	77	92	94	55
10	72	27	11	44	66	61	3	78	182	95	163
11	0.5	28	14	45	74	62	97	79	19	96	44
12	44	29	8	46	106	63	196	80	14	97	19
13	189	30	17	47	120	64	62	81	144	98	0.5
14	19	31	215	48	59	65	118	82	12	99	243
15	39	32	3	49	133	66	1	83	8	100	0.25
16	121	33	0.25	50	262	67	55	84	19		
17	52	34	215	51	26	68	5	85	22		

South Branch Little Aughwick Creek

Reach #: 4 UTM Location: Zone 18, 4429825 m N, 0249153 m E

Composition of Bedload: Consists of tan to red sub-rounded clasts of quartz sandstone, some clasts have a tabular geometry.

Bedload Textures: D50 = 23.0 mm, D84 = 83.0 mm



Pebble Count Data

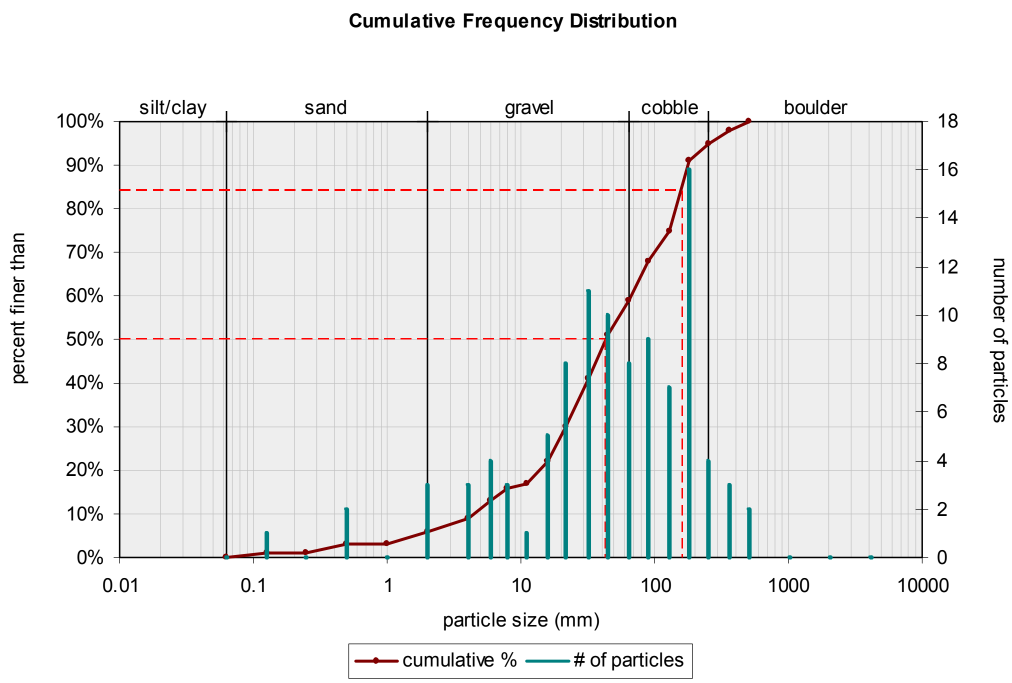
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	14	18	14	35	0.062	52	16	69	0.5	86	17
2	115	19	36	36	20	53	15	70	52	87	16
3	43	20	102	37	14	54	11	71	34	88	68
4	142	21	12	38	6	55	94	72	49	89	22
5	7	22	33	39	8	56	81	73	45	90	98
6	26	23	36	40	27	57	24	74	141	91	19
7	27	24	11	41	6	58	0.062	75	112	92	23
8	21	25	21	42	9	59	2	76	152	93	47
9	9	26	192	43	12	60	48	77	55	94	17
10	22	27	49	44	109	61	47	78	2	95	8
11	237	28	13	45	152	62	9	79	2	96	1
12	0.5	29	8	46	23	63	7	80	13	97	37
13	15	30	24	47	172	64	1	81	12	98	121
14	79	31	77	48	36	65	58	82	11	99	2
15	28	32	33	49	31	66	27	83	3	100	5
16	45	33	7	50	11	67	17	84	0.5		
17	8	34	24	51	49	68	11	85	191		

South Branch Little Aughwick Creek

Reach #: 5   UTM Location: Zone 18, 4430706 m N, 0249706 m E

Composition of Bedload: Consists of tan to red sub-rounded clasts of quartz sandstone, some clasts have a tabular geometry.

Bedload Textures: D50 = 43.0 mm, D84 = 160.0 mm



Pebble Count Data

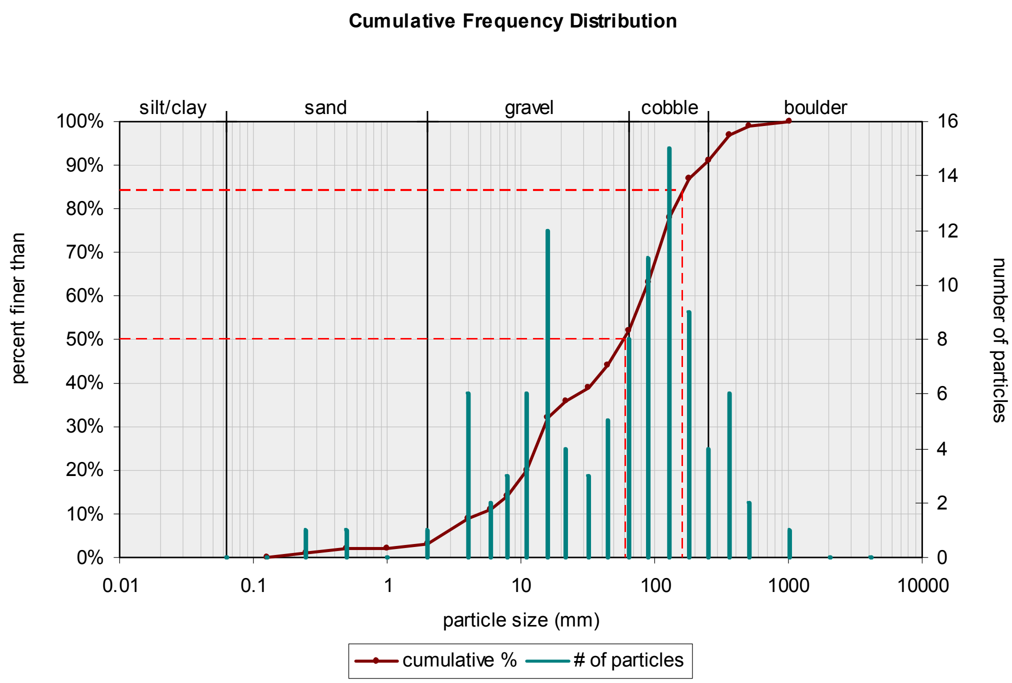
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	135	18	122	35	117	52	141	69	7	86	44
2	33	19	138	36	217	53	72	70	62	87	89
3	19	20	145	37	178	54	364	71	71	88	3
4	21	21	6	38	98	55	221	72	151	89	107
5	39	22	36	39	0.25	56	168	73	0.25	90	143
6	26	23	12	40	391	57	142	74	89	91	229
7	25	24	4	41	274	58	140	75	326	92	96
8	45	25	49	42	23	59	14	76	122	93	77
9	10	26	29	43	21	60	16	77	28	94	261
10	18	27	49	44	32	61	11	78	170	95	1
11	22	28	34	45	129	62	69	79	71	96	4
12	1	29	41	46	89	63	39	80	19	97	132
13	16	30	3	47	0.062	64	24	81	184	98	144
14	39	31	4	48	24	65	4	82	27	99	133
15	11	32	12	49	61	66	61	83	2	100	42
16	147	33	29	50	47	67	19	84	1		
17	88	34	54	51	99	68	3	85	27		

Sherman Creek

<u>Reach #:</u> 6 <u>UTM Location:</u> Zone 18, 4459394 m N, 0276143 m E

<u>Composition of Bedload:</u> Consists of tan to brownish to orange sub-rounded clasts of sandstone.

<u>Bedload Textures:</u> D50 = 59.0 mm, D84 = 160.0 mm



<u>Pebble Count Data</u>

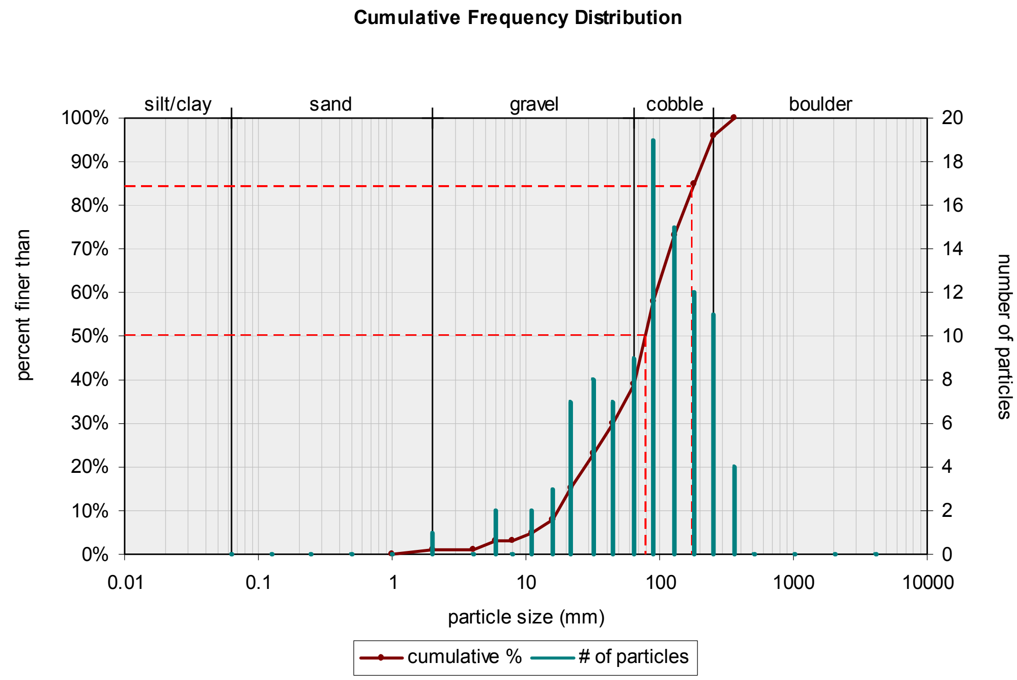
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	63	18	91	35	12	52	175	69	33	86	49
2	11	19	122	36	2	53	603	70	10	87	14
3	152	20	118	37	89	54	138	71	207	88	87
4	6	21	11	38	2	55	68	72	8	89	22
5	310	22	58	39	2	56	244	73	15	90	99
6	19	23	72	40	5	57	17	74	53	91	91
7	7	24	51	41	12	58	68	75	51	92	41
8	492	25	154	42	8	59	112	76	91	93	73
9	317	26	133	43	2	60	0.125	77	87	94	134
10	12	27	198	44	4	61	12	78	68	95	71
11	102	28	22	45	16	62	1	79	10	96	29
12	13	29	76	46	122	63	58	80	8	97	256
13	0.25	30	295	47	491	64	124	81	272	98	14
14	103	31	119	48	129	65	183	82	61	99	45
15	168	32	122	49	40	66	84	83	91	100	2
16	295	33	119	50	106	67	15	84	6		
17	14	34	18	51	2	68	9	85	34		

Sherman Creek

Reach #: 7 UTM Location: Zone 18, 4462068 m N, 0277339 m E

Composition of Bedload: Consists of tan to brownish sub-rounded clasts of sandstone.

Bedload Textures: D50 = 78.0 mm, D84 = 170.0 mm



Pebble Count Data

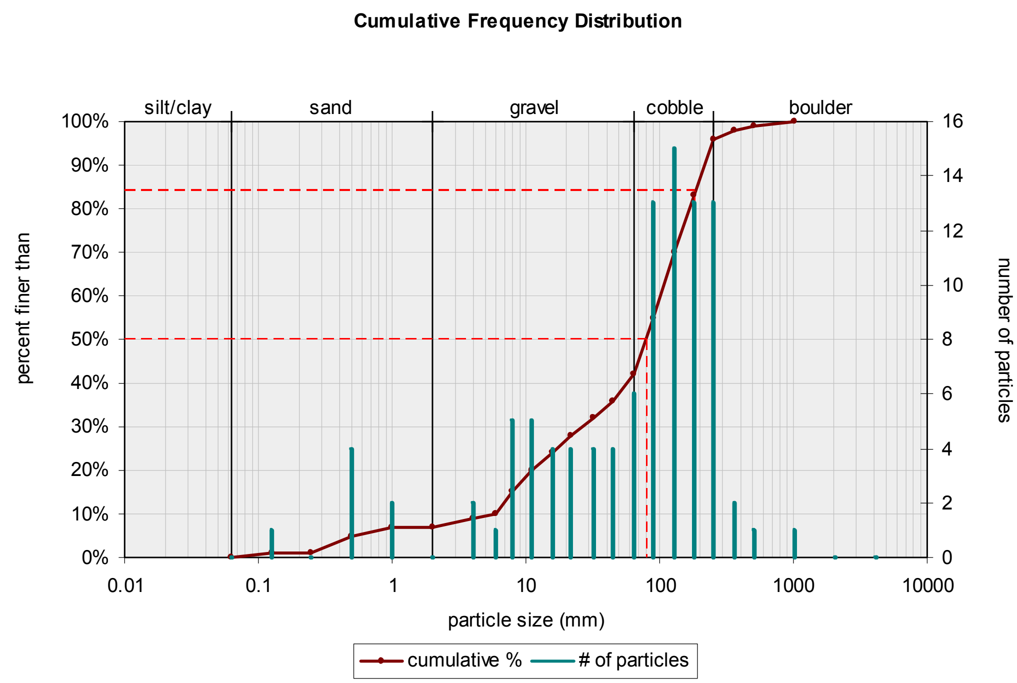
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	317	18	16	35	162	52	70	69	110	86	51
2	30	19	237	36	27	53	361	70	150	87	49
3	66	20	59	37	341	54	293	71	119	88	1
4	52	21	61	38	21	55	86	72	66	89	79
5	71	22	97	39	24	56	51	73	63	90	5
6	142	23	128	40	82	57	129	74	87	91	142
7	101	24	68	41	227	58	25	75	185	92	4
8	95	25	56	42	119	59	127	76	101	93	10
9	34	26	175	43	125	60	64	77	170	94	36
10	15	27	79	44	191	61	40	78	80	95	207
11	28	28	199	45	131	62	14	79	10	96	78
12	22	29	95	46	229	63	29	80	118	97	12
13	216	30	78	47	21	64	224	81	19	98	43
14	49	31	85	48	38	65	87	82	22	99	44
15	79	32	142	49	169	66	19	83	69	100	32
16	115	33	94	50	68	67	199	84	19		
17	19	34	129	51	246	68	98	85	106		

Sherman Creek

Reach #: 8 UTM Location: Zone 18, 4460977 m N, 0275361 m E

Composition of Bedload: Consists of tan sub-rounded to sub-angular clasts of sandstone. Some boulders appear to have a colluvial origin because of their great size.

Bedload Textures: D50 = 79.0 mm, D84 = 180.0 mm



Pebble Count Data

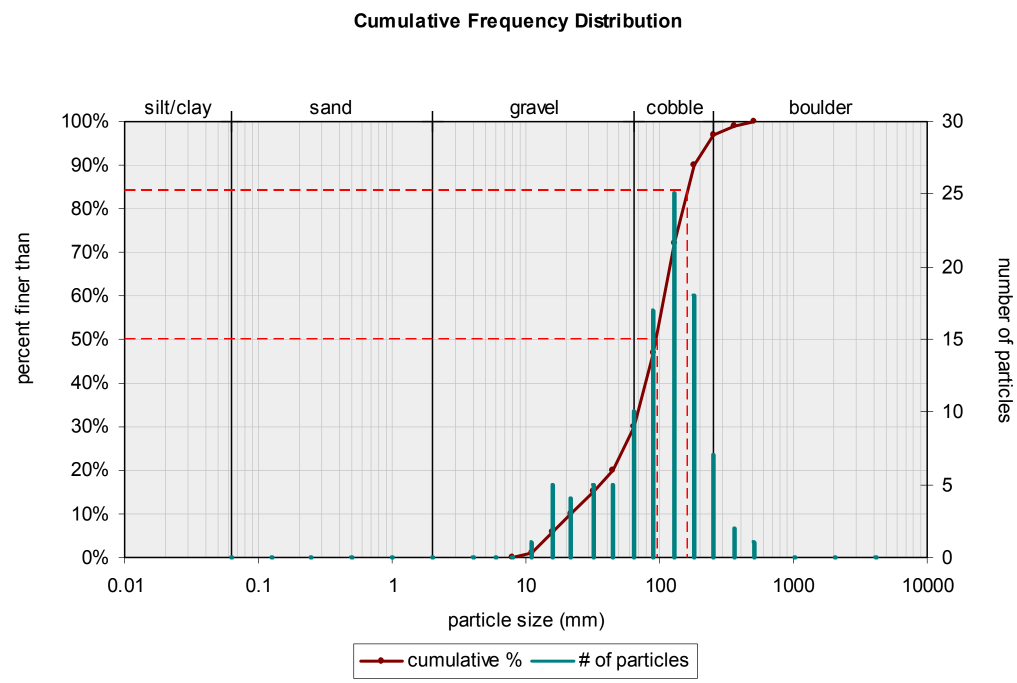
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	231	18	210	35	6	52	77	69	134	86	279
2	9	19	91	36	74	53	98	70	156	87	7
3	14	20	0.062	37	0.25	54	192	71	91	88	3
4	10	21	96	38	196	55	123	72	144	89	62
5	112	22	12	39	70	56	53	73	84	90	234
6	17	23	29	40	0.25	57	106	74	7	91	6
7	163	24	66	41	89	58	13	75	92	92	109
8	87	25	69	42	9	59	10	76	188	93	137
9	176	26	75	43	0.25	60	92	77	19	94	122
10	0.25	27	212	44	39	61	0.5	78	39	95	118
11	137	28	13	45	49	62	232	79	201	96	94
12	84	29	69	46	46	63	20	80	219	97	222
13	46	30	154	47	153	64	89	81	23	98	17
14	134	31	261	48	27	65	2	82	204	99	19
15	429	32	765	49	187	66	9	83	142	100	33
16	140	33	43	50	7	67	87	84	99		
17	4	34	0.5	51	173	68	51	85	96		

Sherman Creek

Reach #: 9 UTM Location: Zone 18, 4463007 m N, 0278568 m E

Composition of Bedload: Consists of tan to red sub-rounded to rounded clasts of clean sandstone.

Bedload Textures: D50 = 94.0 mm, D84 = 160.0 mm



Pebble Count Data

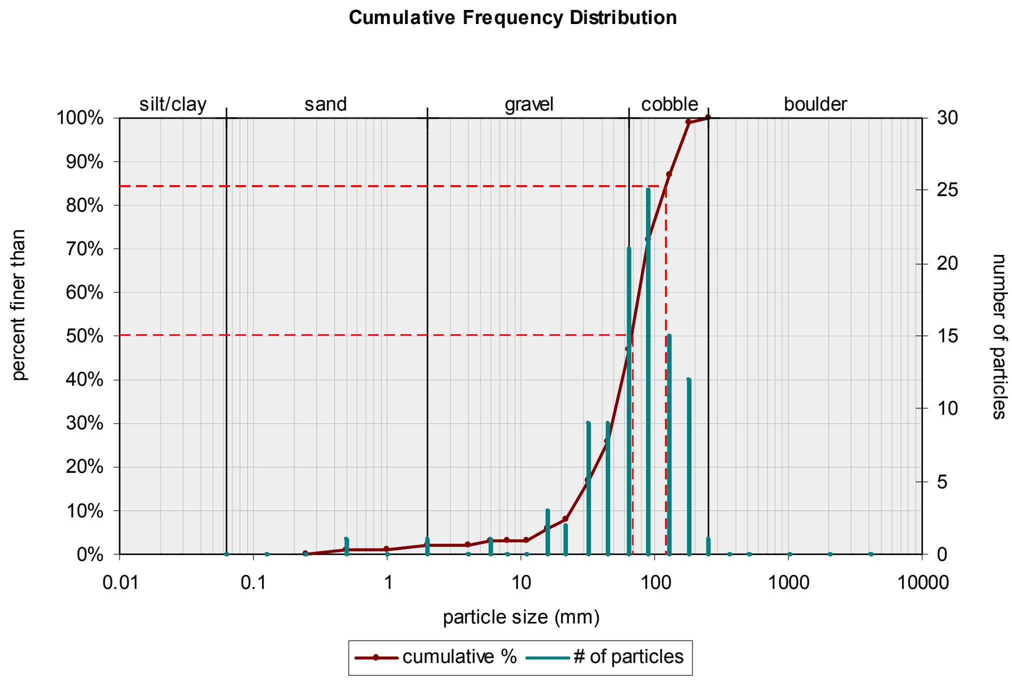
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	15	18	63	35	102	52	27	69	119	86	230
2	76	19	103	36	87	53	71	70	138	87	93
3	154	20	124	37	74	54	78	71	100	88	114
4	17	21	111	38	58	55	77	72	97	89	109
5	149	22	59	39	57	56	99	73	19	90	112
6	91	23	112	40	104	57	81	74	29	91	184
7	186	24	164	41	113	58	113	75	132	92	19
8	158	25	82	42	85	59	33	76	77	93	112
9	18	26	49	43	38	60	230	77	212	94	118
10	109	27	12	44	81	61	159	78	24	95	10
11	151	28	166	45	92	62	26	79	65	96	281
12	124	29	144	46	49	63	162	80	136	97	24
13	142	30	61	47	13	64	96	81	53	98	68
14	207	31	83	48	14	65	147	82	171	99	37
15	102	32	11	49	131	66	42	83	59	100	39
16	106	33	58	50	475	67	76	84	76		
17	132	34	352	51	142	68	190	85	68		

Sherman Creek

Reach #: 10 UTM Location: Zone 18, 4463657 m N, 0279647 m E

Composition of Bedload: Consists of rounded to sub-rounded clasts of sandstone.

Bedload Textures: D50 = 67.0 mm, D84 = 120.0 mm



Pebble Count Data

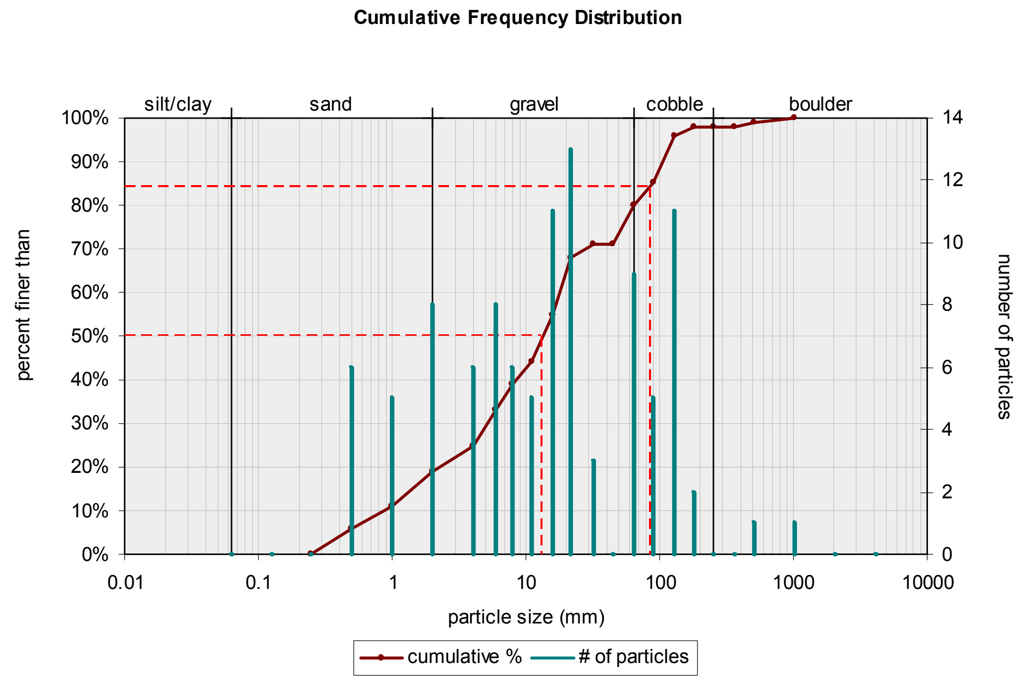
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	54	18	72	35	82	52	101	69	16	86	34
2	79	19	61	36	69	53	154	70	93	87	84
3	22	20	55	37	47	54	47	71	52	88	136
4	67	21	138	38	82	55	24	72	193	89	86
5	81	22	44	39	12	56	96	73	127	90	33
6	102	23	36	40	82	57	27	74	121	91	74
7	49	24	129	41	100	58	45	75	71	92	109
8	72	25	62	42	66	59	39	76	64	93	241
9	51	26	59	43	71	60	29	77	82	94	27
10	55	27	58	44	101	61	48	78	98	95	39
11	89	28	57	45	157	62	15	79	49	96	26
12	91	29	31	46	78	63	140	80	22	97	4
13	83	30	51	47	64	64	142	81	11	98	0.25
14	71	31	32	48	86	65	44	82	1	99	26
15	179	32	118	49	141	66	36	83	107	100	68
16	133	33	21	50	55	67	47	84	49		
17	178	34	119	51	113	68	159	85	54		

Sherman Creek

Reach #: 11 UTM Location: Zone 18, 4460667 m N, 0274457 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 13.0 mm, D84 = 84.0 mm



Pebble Count Data

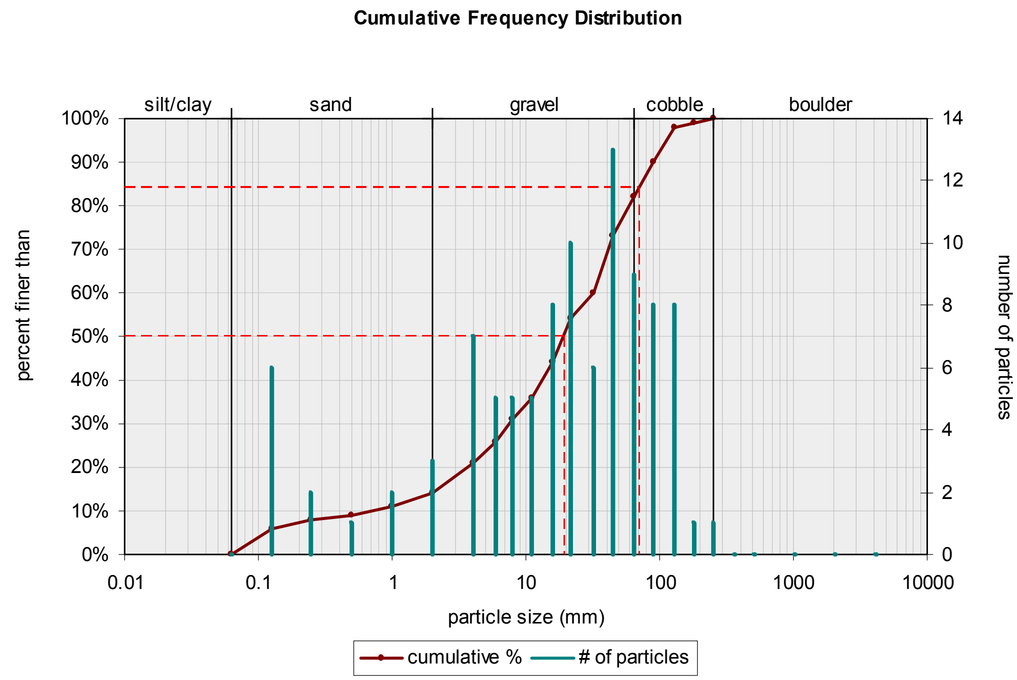
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	5	18	114	35	14	52	16	69	19	86	5
2	4	19	0.5	36	4	53	8	70	49	87	1
3	56	20	12	37	464	54	1	71	27	88	12
4	113	21	58	38	12	55	2	72	17	89	9
5	121	22	7	39	69	56	4	73	7	90	81
6	17	23	5	40	109	57	104	74	905	91	0.5
7	89	24	13	41	16	58	0.25	75	16	92	0.25
8	116	25	49	42	24	59	69	76	7	93	7
9	0.25	26	111	43	3	60	18	77	52	94	11
10	0.5	27	54	44	8	61	26	78	101	95	0.25
11	7	28	19	45	4	62	11	79	19	96	0.5
12	1	29	56	46	3	63	5	80	8	97	1
13	13	30	131	47	69	64	3	81	0.35	98	1
14	11	31	9	48	16	65	0.71	82	12	99	139
15	62	32	2	49	1	66	7	83	16	100	13
16	96	33	17	50	2	67	1	84	119		
17	17	34	0.25	51	106	68	1	85	47		

Horse Valley Run

Reach #: 12 UTM Location: Zone 18, 4465262 m N, 0276227 m E

Composition of Bedload: Consists of clasts of sandstone, covered with slimy layer of silt and clay..

Bedload Textures: D50 = 19.0 mm, D84 = 70.0 mm



Pebble Count Data

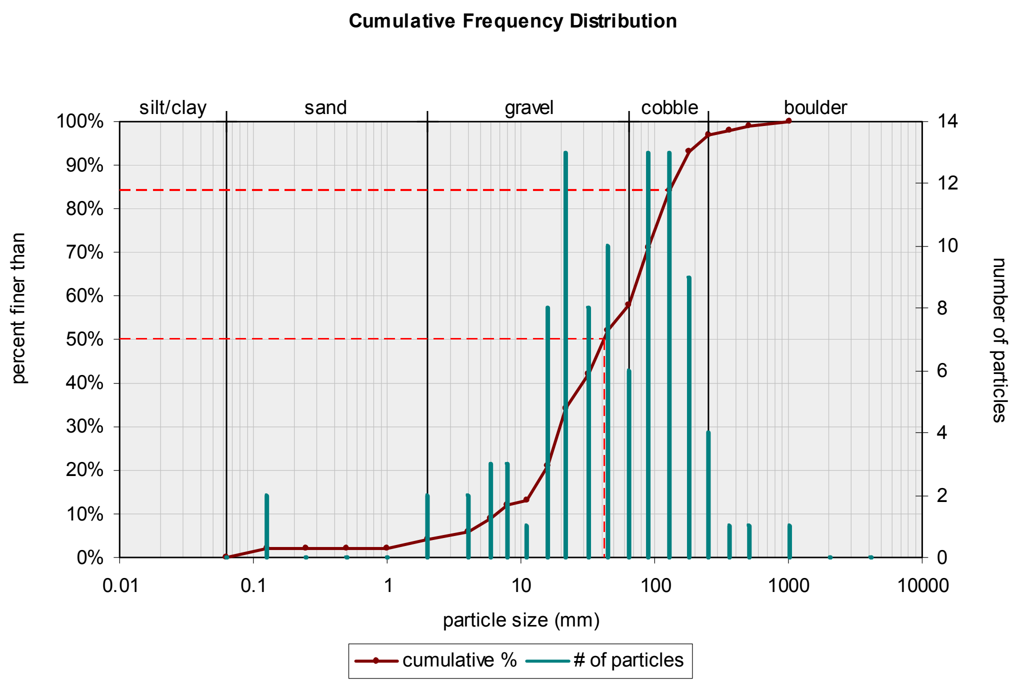
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	72	18	5	35	109	52	85	69	10	86	7
2	104	19	9	36	36	53	21	70	121	87	9
3	32	20	6	37	14	54	34	71	16	88	107
4	12	21	9	38	31	55	32	72	10	89	0.062
5	88	22	2	39	16	56	19	73	4	90	0.5
6	22	23	44	40	4	57	42	74	2	91	2
7	31	24	38	41	3	58	36	75	14	92	3
8	24	25	19	42	16	59	0.125	76	3	93	33
9	6	26	77	43	7	60	81	77	46	94	37
10	15	27	18	44	3	61	0.062	78	55	95	63
11	0.062	28	62	45	1	62	34	79	29	96	11
12	11	29	36	46	52	63	13	80	88	97	1
13	0.062	30	0.125	47	70	64	52	81	19	98	4
14	54	31	0.25	48	48	65	68	82	24	99	6
15	36	32	0.062	49	17	66	125	83	0.062	100	1
16	140	33	0.5	50	113	67	118	84	20		
17	4	34	60	51	98	68	206	85	12		

Horse Valley Run

Reach #: 13 UTM Location: Zone 18, 4469394 m N, 0279428 m E

Composition of Bedload: Consists of sub-rounded to rounded clasts of sandstone, covered with silt and clay.

Bedload Textures: D50 = 42.0 mm, D84 = 130.0 mm



Pebble Count Data

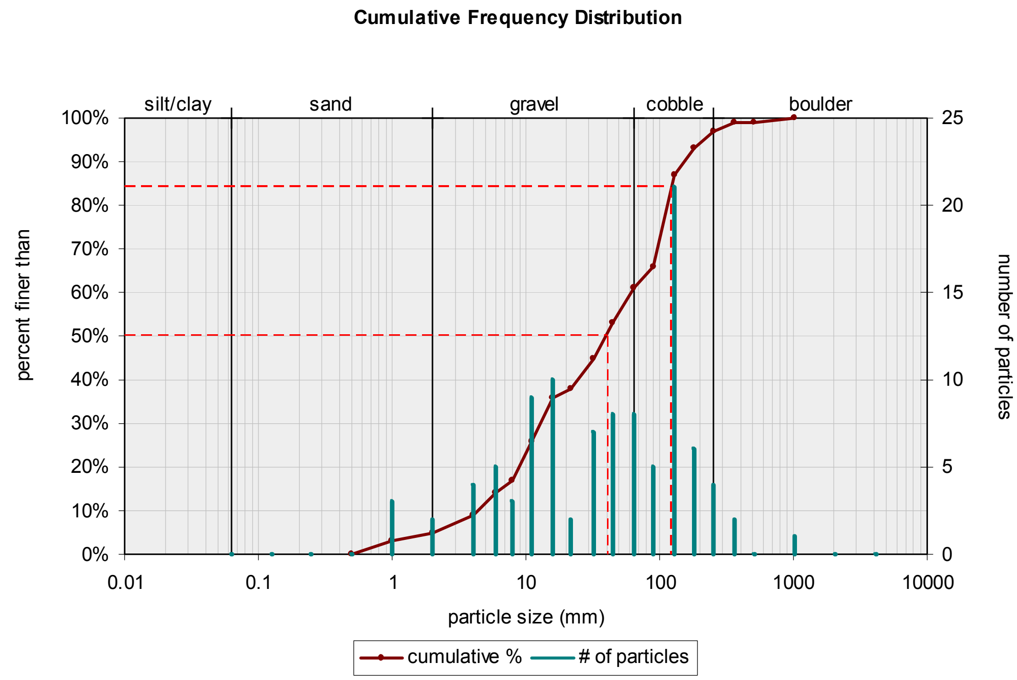
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	13	18	20	35	88	52	209	69	119	86	61
2	14	19	16	36	1	53	46	70	437	87	38
3	69	20	6	37	2	54	775	71	118	88	21
4	124	21	18	38	4	55	82	72	5	89	0.062
5	152	22	12	39	79	56	112	73	101	90	35
6	42	23	7	40	23	57	29	74	166	91	61
7	29	24	152	41	21	58	334	75	121	92	42
8	123	25	69	42	84	59	18	76	4	93	22
9	21	26	119	43	11	60	19	77	7	94	34
10	103	27	131	44	17	61	78	78	21	95	12
11	43	28	86	45	29	62	67	79	30	96	24
12	46	29	173	46	178	63	91	80	12	97	171
13	16	30	22	47	91	64	122	81	35	98	14
14	36	31	238	48	233	65	14	82	21	99	1
15	21	32	0.062	49	44	66	243	83	69	100	69
16	47	33	92	50	162	67	9	84	86		
17	32	34	78	51	49	68	2	85	174		

Horse Valley Run

Reach #: 14 UTM Location: Zone 18, 4469188 m N, 0280073 m E

Composition of Bedload: Consists of sub-rounded to sub-angular clasts of sandstone.

Bedload Textures: D50 = 40.0 mm, D84 = 120.0 mm



Pebble Count Data

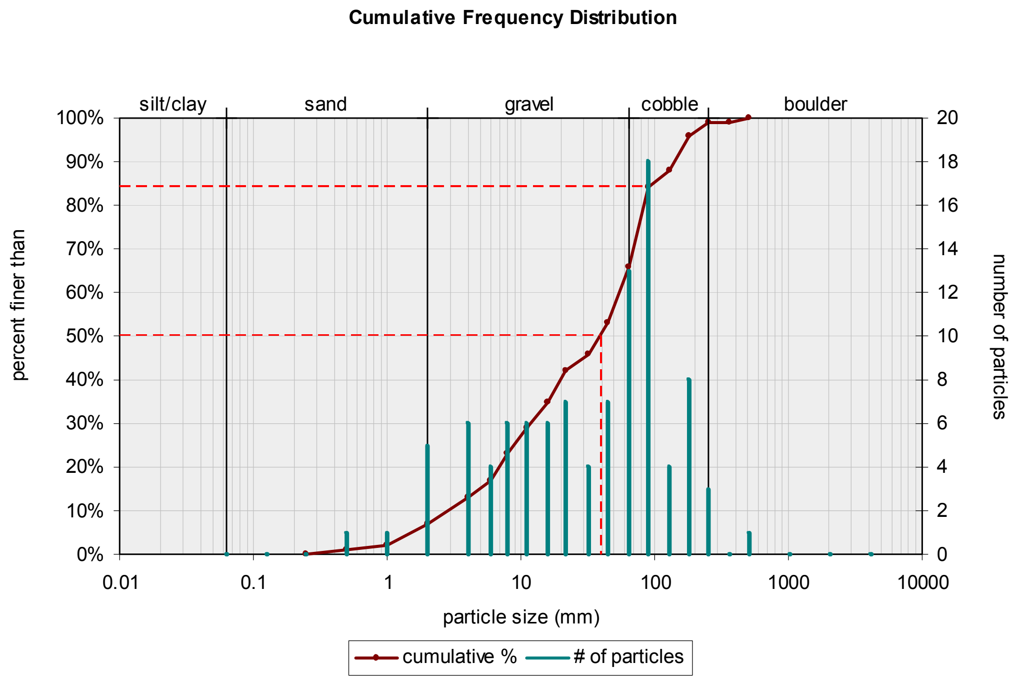
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	173	18	14	35	153	52	6	69	8	86	0.5
2	9	19	8	36	92	53	2	70	4	87	102
3	91	20	125	37	96	54	7	71	107	88	110
4	34	21	116	38	93	55	37	72	128	89	31
5	41	22	8	39	127	56	0.5	73	84	90	93
6	92	23	33	40	96	57	56	74	105	91	13
7	182	24	10	41	5	58	9	75	49	92	14
8	307	25	25	42	24	59	101	76	19	93	11
9	54	26	13	43	8	60	19	77	43	94	74
10	60	27	7	44	125	61	4	78	11	95	141
11	29	28	18	45	3	62	36	79	100	96	22
12	57	29	44	46	0.5	63	22	80	67	97	134
13	77	30	8	47	4	64	12	81	202	98	1
14	28	31	107	48	11	65	36	82	54	99	2
15	596	32	72	49	3	66	14	83	141	100	4
16	109	33	204	50	62	67	1	84	119		
17	107	34	11	51	55	68	274	85	8		

Horse Valley Run

Reach #: 15 UTM Location: Zone 18, 4469562 m N, 0281022 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 39.0 mm, D84 = 90.0 mm



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	142	18	39	35	117	52	17	69	3	86	192
2	36	19	17	36	109	53	136	70	91	87	144
3	66	20	3	37	4	54	61	71	17	88	0.25
4	9	21	2	38	86	55	89	72	21	89	69
5	64	22	1	39	12	56	3	73	6	90	43
6	88	23	4	40	87	57	1	74	37	91	49
7	27	24	62	41	79	58	71	75	37	92	67
8	134	25	37	42	166	59	4	76	54	93	121
9	54	26	79	43	13	60	21	77	49	94	10
10	138	27	62	44	72	61	54	78	13	95	7
11	129	28	3	45	51	62	6	79	1	96	1
12	14	29	36	46	57	63	8	80	10	97	198
13	77	30	47	47	27	64	7	81	3	98	66
14	206	31	28	48	7	65	29	82	16	99	7
15	161	32	84	49	78	66	17	83	5	100	0.5
16	378	33	67	50	13	67	10	84	11		
17	66	34	49	51	9	68	1	85	45		

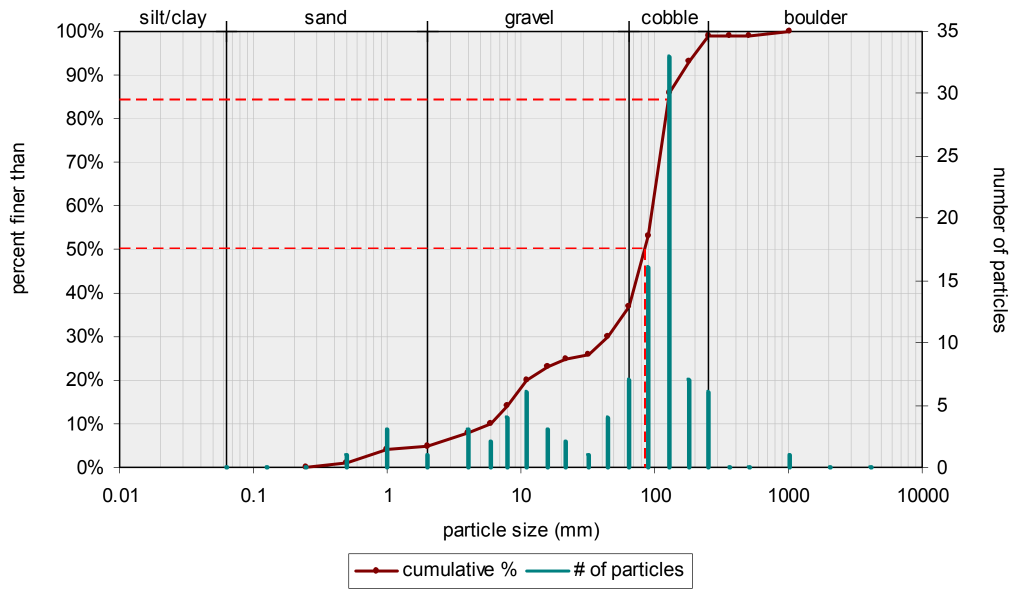
Horse Valley Run

Reach #: 16 UTM Location: Zone 18, 4470266 m N, 0281647 m E

Composition of Bedload: Consists of sub-rounded clasts of tan to red sandstone.

Bedload Textures: D50 = 84.0 mm, D84 = 130.0 mm

Cumulative Frequency Distribution



Pebble Count Data

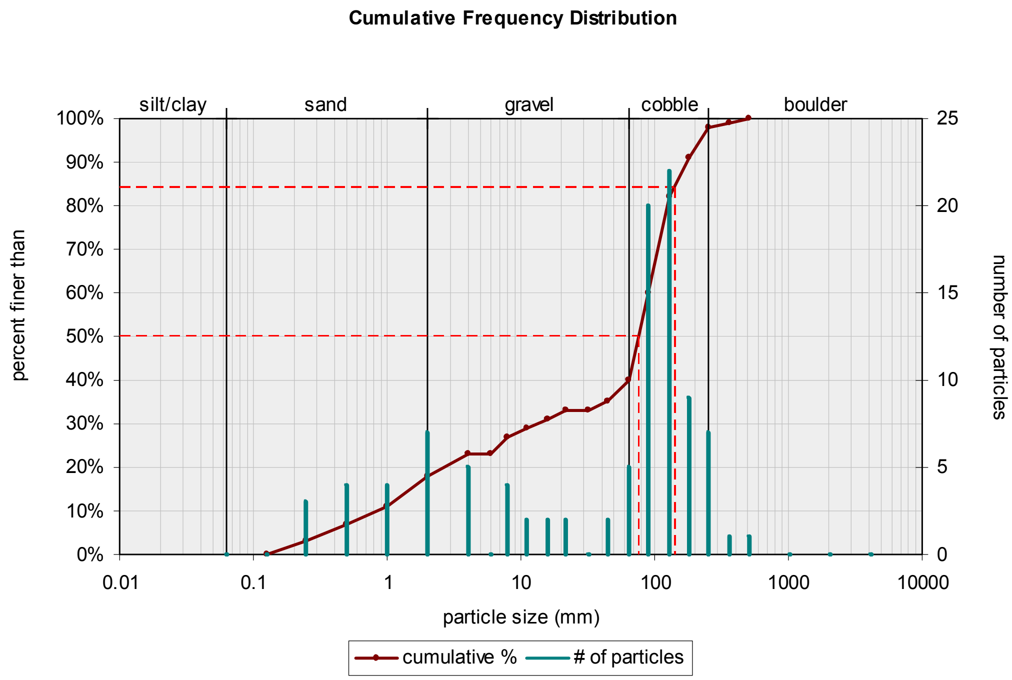
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	106	18	3	35	10	52	0.25	69	0.5	86	111
2	84	19	17	36	81	53	86	70	0.9	87	127
3	216	20	6	37	5	54	113	71	36	88	153
4	96	21	1	38	135	55	109	72	6	89	75
5	13	22	185	39	107	56	68	73	3	90	119
6	165	23	107	40	249	57	145	74	79	91	0.5
7	51	24	12	41	8	58	642	75	97	92	118
8	234	25	5	42	101	59	101	76	102	93	96
9	91	26	8	43	35	60	122	77	98	94	68
10	100	27	66	44	121	61	96	78	87	95	54
11	95	28	237	45	82	62	101	79	103	96	101
12	37	29	158	46	87	63	181	80	118	97	9
13	56	30	68	47	10	64	49	81	112	98	68
14	93	31	26	48	169	65	111	82	121	99	130
15	57	32	51	49	7	66	81	83	79	100	127
16	32	33	6	50	21	67	114	84	3		
17	70	34	15	51	97	68	49	85	9		

Horse Valley Run

Reach #: 17 UTM Location: Zone 18, 4470482 m N, 0282011 m E

Composition of Bedload: Consists of sub-angular to sub-rounded clasts of sandstone and abundant sand size grains.

Bedload Textures: D50 = 76.0 mm, D84 = 140.0 mm



Pebble Count Data

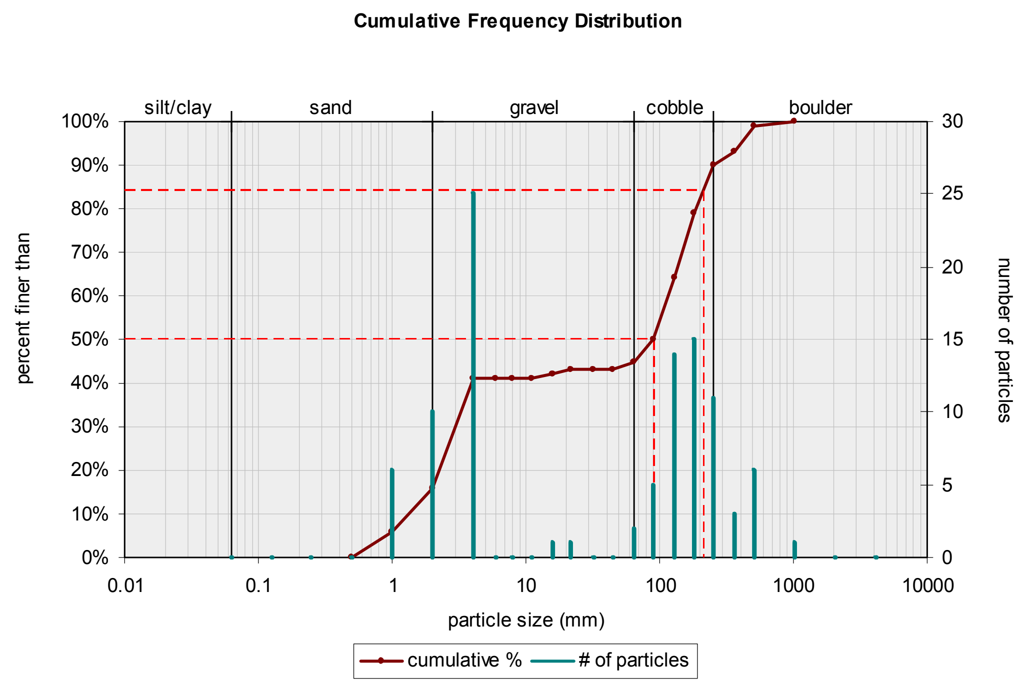
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	74	18	2	35	174	52	0.125	69	1	86	2
2	0.25	19	97	36	68	53	117	70	74	87	53
3	94	20	160	37	155	54	0.25	71	8	88	1
4	111	21	97	38	84	55	57	72	127	89	242
5	79	22	180	39	1	56	2	73	138	90	96
6	256	23	0.125	40	72	57	93	74	82	91	7
7	127	24	64	41	0.5	58	84	75	91	92	6
8	1	25	91	42	224	59	61	76	1	93	109
9	14	26	79	43	9	60	124	77	116	94	221
10	0.5	27	88	44	2	61	0.5	78	79	95	201
11	0.5	28	36	45	153	62	380	79	119	96	62
12	129	29	74	46	94	63	86	80	44	97	66
13	127	30	109	47	15	64	0.25	81	54	98	112
14	83	31	204	48	158	65	87	82	129	99	131
15	114	32	0.25	49	16	66	86	83	1	100	1
16	17	33	0.125	50	79	67	2	84	7		
17	122	34	7	51	109	68	220	85	73		

Laurel Run

Reach #: 18 UTM Location: Zone 18, 4455800 m N, 0281525 m E

Composition of Bedload: Consists of tan, tabular, sub-rounded clasts of sandstone and sand size grains.

Bedload Textures: D50 = 90.0 mm, D84 = 210.0 mm



Pebble Count Data

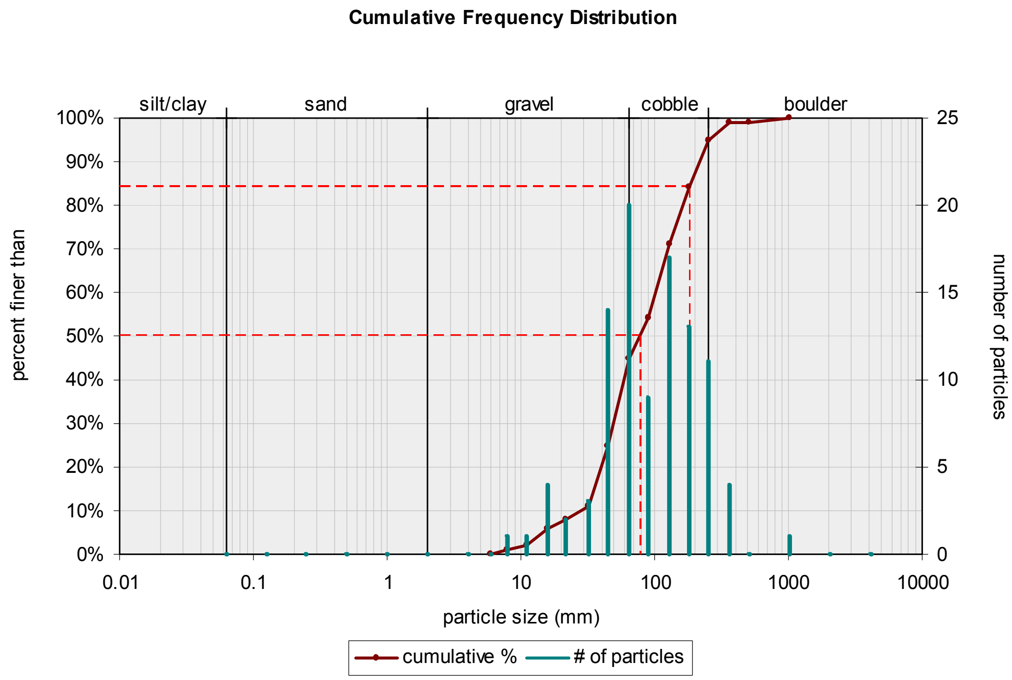
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	119	18	203	35	1	52	101	69	0.5	86	1
2	647	19	2	36	101	53	1	70	130	87	2
3	196	20	2	37	0.5	54	94	71	99	88	1
4	134	21	136	38	2	55	182	72	2	89	79
5	375	22	278	39	139	56	274	73	93	90	55
6	2	23	2	40	97	57	0.5	74	2	91	1
7	195	24	113	41	402	58	181	75	1	92	164
8	12	25	2	42	2	59	222	76	0.5	93	223
9	3	26	3	43	56	60	2	77	112	94	82
10	1	27	1	44	133	61	142	78	1	95	99
11	2	28	129	45	0.5	62	78	79	2	96	140
12	3	29	142	46	2	63	153	80	489	97	19
13	158	30	2	47	2	64	3	81	173	98	351
14	209	31	97	48	2	65	2	82	132	99	2
15	79	32	187	49	224	66	241	83	120	100	0.5
16	368	33	1	50	2	67	104	84	461		
17	2	34	146	51	492	68	87	85	109		

Laurel Run

Reach #: 19 UTM Location: Zone 18, 4455793 m N, 0284851 m E

Composition of Bedload: Consists of sub-rounded, tan to red, clasts of sandstone.

Bedload Textures: D50 = 77.0 mm, D84 = 180.0 mm



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	104	18	106	35	333	52	48	69	62	86	69
2	10	19	619	36	136	53	7	70	53	87	113
3	250	20	59	37	96	54	163	71	202	88	11
4	42	21	32	38	169	55	58	72	260	89	68
5	43	22	311	39	58	56	74	73	31	90	196
6	21	23	26	40	59	57	112	74	38	91	13
7	89	24	189	41	47	58	143	75	126	92	99
8	112	25	116	42	63	59	115	76	74	93	100
9	54	26	58	43	61	60	134	77	273	94	48
10	134	27	37	44	142	61	131	78	121	95	71
11	183	28	36	45	184	62	39	79	71	96	37
12	42	29	34	46	146	63	77	80	63	97	31
13	139	30	105	47	37	64	61	81	61	98	210
14	13	31	89	48	34	65	152	82	151	99	131
15	216	32	17	49	202	66	61	83	54	100	91
16	43	33	105	50	99	67	11	84	47		
17	96	34	55	51	208	68	39	85	255		

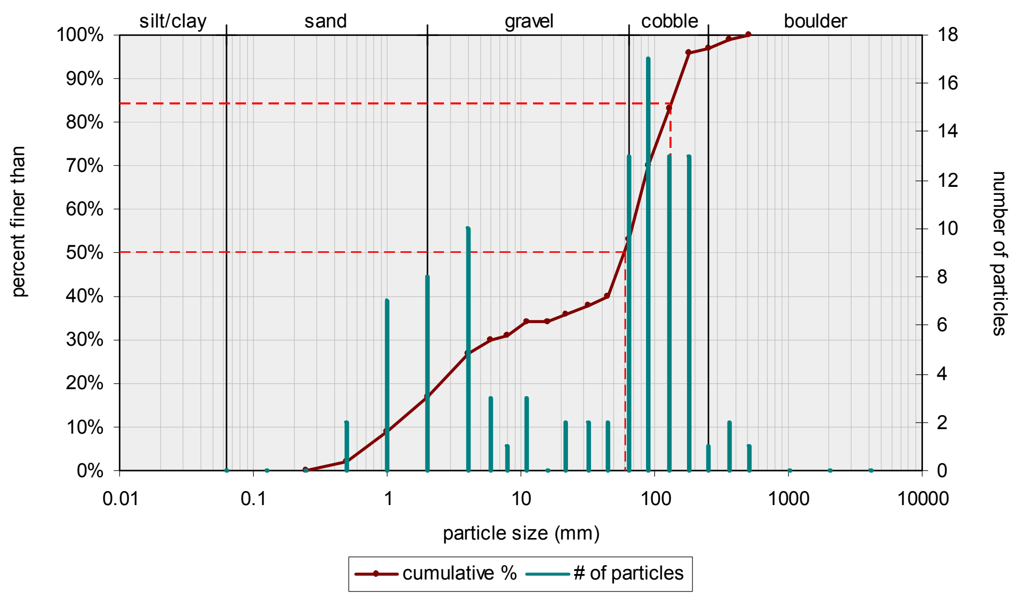
Laurel Run

Reach #: 20 UTM Location: Zone 18, 4455305 m N, 0281027 m E

Composition of Bedload: Consists of sub-angular to sub-rounded tan clasts of sandstone, abundant sand size grains.

Bedload Textures: D50 = 59.0 mm, D84 = 130.0 mm

Cumulative Frequency Distribution



Pebble Count Data

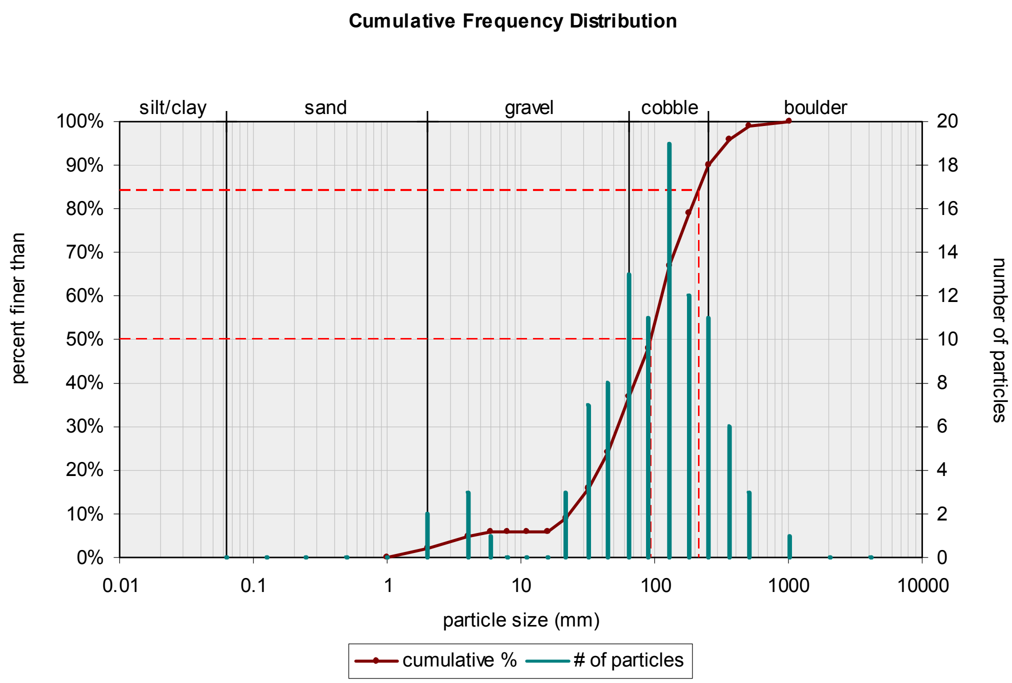
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	64	18	88	35	48	52	2	69	77	86	29
2	129	19	65	36	59	53	51	70	100	87	7
3	99	20	1	37	62	54	2	71	55	88	68
4	164	21	2	38	1	55	113	72	71	89	81
5	76	22	0.25	39	1	56	57	73	88	90	215
6	79	23	0.25	40	2	57	3	74	1	91	38
7	141	24	5	41	261	58	350	75	89	92	57
8	0.5	25	147	42	16	59	61	76	173	93	81
9	83	26	58	43	2	60	2	77	138	94	3
10	489	27	1	44	63	61	52	78	78	95	0.5
11	0.5	28	4	45	9	62	133	79	0.5	96	124
12	87	29	142	46	10	63	49	80	140	97	1
13	172	30	4	47	140	64	0.5	81	61	98	69
14	111	31	42	48	20	65	27	82	0.5	99	2
15	148	32	1	49	94	66	107	83	124	100	101
16	98	33	69	50	104	67	4	84	108		
17	111	34	2	51	0.5	68	9	85	163		

Laurel Run

Reach #: 21 UTM Location: Zone 18, 4456176 m N, 0281989 m E

Composition of Bedload: Consists of tabular, sub-angular to sub-rounded clasts of clean quartz sandstone.

Bedload Textures: D50 = 93.0 mm, D84 = 210.0 mm



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	43	18	51	35	135	52	161	69	44	86	118
2	45	19	63	36	216	53	92	70	594	87	154
3	22	20	118	37	1	54	69	71	46	88	219
4	25	21	102	38	129	55	150	72	180	89	77
5	47	22	100	39	243	56	33	73	157	90	420
6	70	23	350	40	321	57	39	74	193	91	102
7	119	24	14	41	66	58	42	75	24	92	29
8	112	25	22	42	28	59	41	76	98	93	91
9	20	26	133	43	91	60	2	77	2	94	305
10	44	27	19	44	55	61	4	78	59	95	71
11	181	28	331	45	78	62	80	79	93	96	22
12	2	29	89	46	91	63	169	80	138	97	183
13	491	30	193	47	155	64	180	81	54	98	111
14	221	31	41	48	119	65	93	82	237	99	127
15	165	32	397	49	67	66	47	83	79	100	104
16	49	33	59	50	51	67	142	84	1		
17	48	34	109	51	285	68	300	85	68		

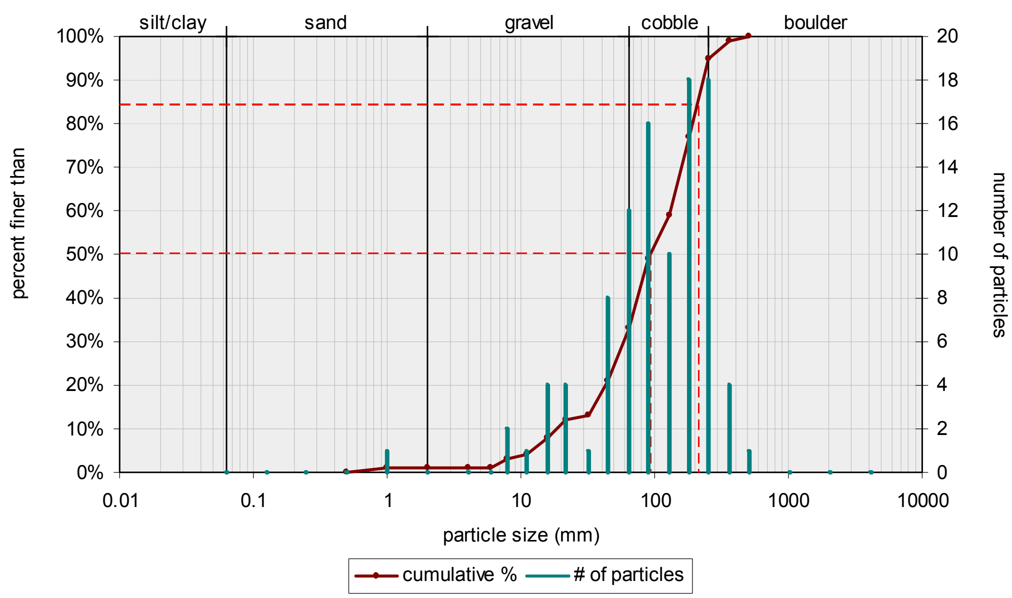
Laurel Run

Reach #: 22 UTM Location: Zone 18, 4459957 m N, 0288247 m E

Composition of Bedload: Consists of tan sub-angular to sub-rounded clasts of sandstone.

Bedload Textures: D50 = 93.0 mm, D84 = 210.0 mm

Cumulative Frequency Distribution



Pebble Count Data

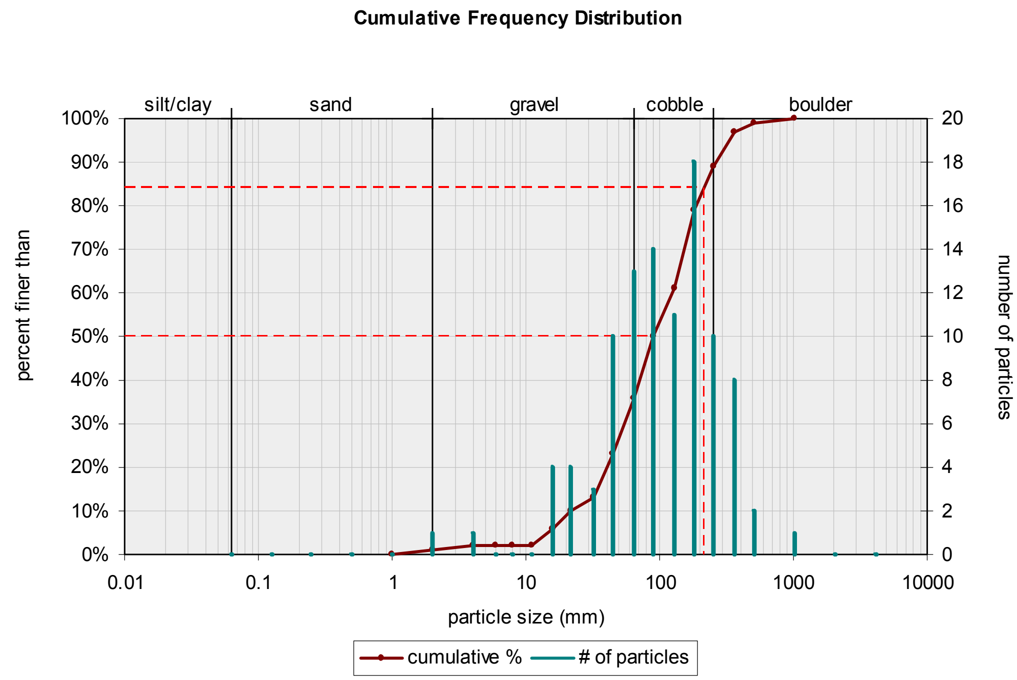
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	192	18	211	35	114	52	60	69	337	86	66
2	72	19	113	36	14	53	29	70	181	87	37
3	889	20	76	37	13	54	80	71	181	88	63
4	155	21	143	38	17	55	11	72	139	89	229
5	163	22	185	39	129	56	0.5	73	231	90	49
6	110	23	291	40	49	57	83	74	185	91	96
7	247	24	148	41	128	58	6	75	83	92	71
8	140	25	135	42	234	59	20	76	42	93	44
9	204	26	59	43	119	60	51	77	68	94	7
10	191	27	176	44	281	61	61	78	37	95	111
11	39	28	82	45	198	62	106	79	14	96	20
12	109	29	19	46	42	63	129	80	82	97	136
13	141	30	38	47	303	64	47	81	129	98	51
14	91	31	64	48	32	65	84	82	193	99	231
15	50	32	9	49	81	66	63	83	189	100	104
16	71	33	207	50	72	67	158	84	135		
17	49	34	168	51	221	68	201	85	416		

Laurel Run

Reach #: 23 UTM Location: Zone 18, 4460052 m N, 0288307 m E

Composition of Bedload: Consists of elongate, tabular, sub-angular to sub-rounded clasts of sandstone.

Bedload Textures: D50 = 90.0 mm, D84 = 210.0 mm



Pebble Count Data

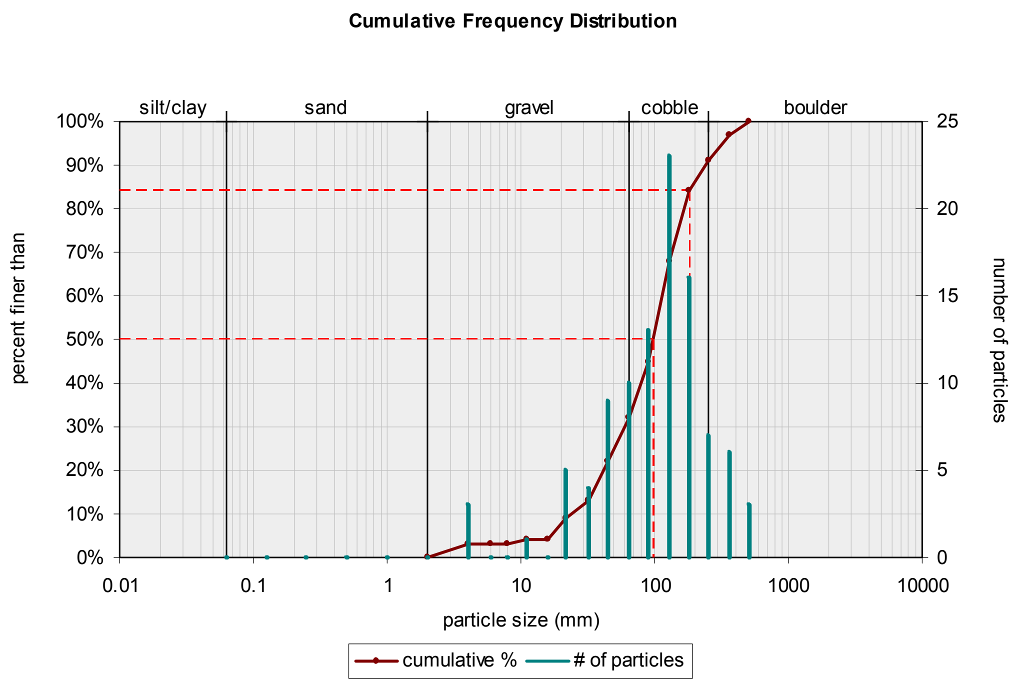
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	123	18	143	35	113	52	78	69	46	86	27
2	36	19	63	36	160	53	359	70	68	87	173
3	17	20	140	37	47	54	43	71	395	88	161
4	332	21	90	38	3	55	593	72	104	89	66
5	55	22	1	39	61	56	188	73	45	90	177
6	15	23	144	40	66	57	11	74	113	91	24
7	20	24	211	41	49	58	37	75	378	92	11
8	27	25	195	42	179	59	66	76	133	93	41
9	40	26	342	43	130	60	288	77	34	94	47
10	20	27	86	44	361	61	36	78	192	95	41
11	53	28	149	45	68	62	289	79	194	96	83
12	111	29	171	46	147	63	109	80	84	97	151
13	60	30	59	47	143	64	47	81	110	98	103
14	131	31	247	48	82	65	43	82	209	99	130
15	295	32	259	49	51	66	79	83	344	100	19
16	40	33	88	50	211	67	74	84	241		
17	75	34	99	51	126	68	177	85	14		

Laurel Run

Reach #: 24 UTM Location: Zone 18, 4461110 m N, 0290814 m E

Composition of Bedload: Consists of red and tan sub-angular to sub-rounded clasts of sandstone.

Bedload Textures: D50 = 97.0 mm, D84 = 180.0 mm



Pebble Count Data

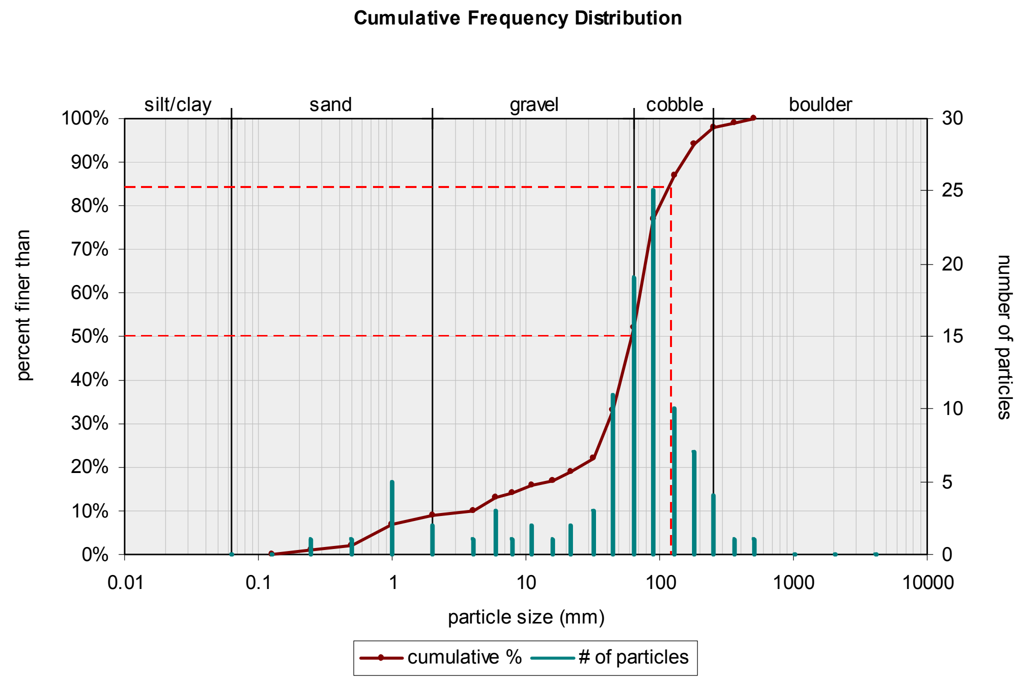
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	21	18	61	35	101	52	135	69	85	86	87
2	90	19	65	36	134	53	94	70	59	87	201
3	141	20	151	37	21	54	115	71	187	88	94
4	208	21	143	38	120	55	284	72	56	89	73
5	277	22	423	39	106	56	104	73	173	90	79
6	121	23	32	40	103	57	48	74	62	91	44
7	93	24	81	41	8	58	49	75	49	92	18
8	58	25	39	42	122	59	287	76	77	93	111
9	113	26	72	43	44	60	121	77	419	94	17
10	149	27	104	44	123	61	2	78	104	95	93
11	146	28	186	45	19	62	73	79	132	96	86
12	191	29	155	46	25	63	24	80	52	97	341
13	35	30	364	47	102	64	140	81	321	98	150
14	139	31	131	48	39	65	38	82	36	99	3
15	22	32	116	49	144	66	76	83	69	100	210
16	98	33	27	50	77	67	165	84	191		
17	56	34	115	51	3	68	44	85	292		

Conodoguinet Creek

Reach #: 25 UTM Location: Zone 18, 4442218 m N, 0268887 m E

Composition of Bedload: Consists of tan, tabular to elongate, sub-angular to sub-rounded clasts of sandstone.

Bedload Textures: D50 = 62.0 mm, D84 = 120.0 mm



Pebble Count Data

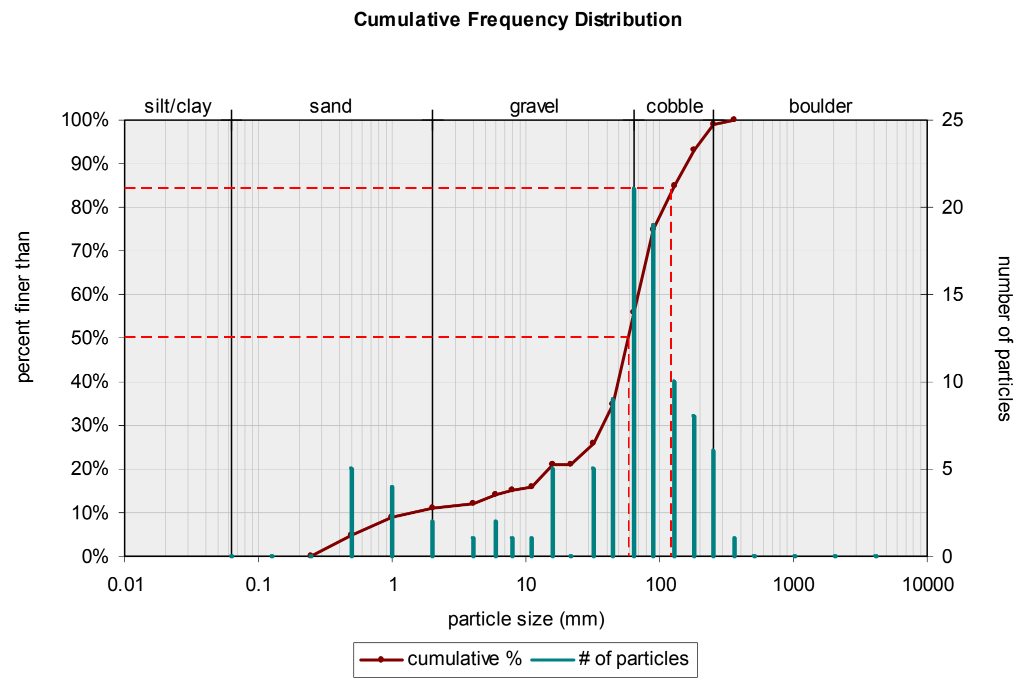
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	1	18	69	35	55	52	44	69	380	86	53
2	210	19	58	36	61	53	47	70	235	87	44
3	105	20	65	37	89	54	70	71	240	88	94
4	8	21	115	38	43	55	120	72	83	89	80
5	57	22	70	39	22	56	105	73	58	90	79
6	66	23	0.25	40	34	57	89	74	62	91	74
7	77	24	150	41	0.5	58	160	75	66	92	16
8	0.5	25	100	42	62	59	85	76	80	93	79
9	72	26	85	43	40	60	85	77	28	94	63
10	33	27	33	44	93	61	46	78	44	95	153
11	85	28	46	45	53	62	0.5	79	61	96	69
12	150	29	185	46	160	63	2.6	80	130	97	32
13	145	30	69	47	265	64	5.2	81	0.71	98	14
14	46	31	0.125	48	43	65	5.2	82	31	99	75
15	1	32	53	49	95	66	5.2	83	57	100	0.5
16	111	33	39	50	65	67	9.6	84	54		
17	80	34	60	51	100	68	6.3	85	21		

Conodoguinet Creek

Reach #: 26 UTM Location: Zone 18, 4440721 m N, 0266815 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 58.0 mm, D84 = 120.0 mm



Pebble Count Data

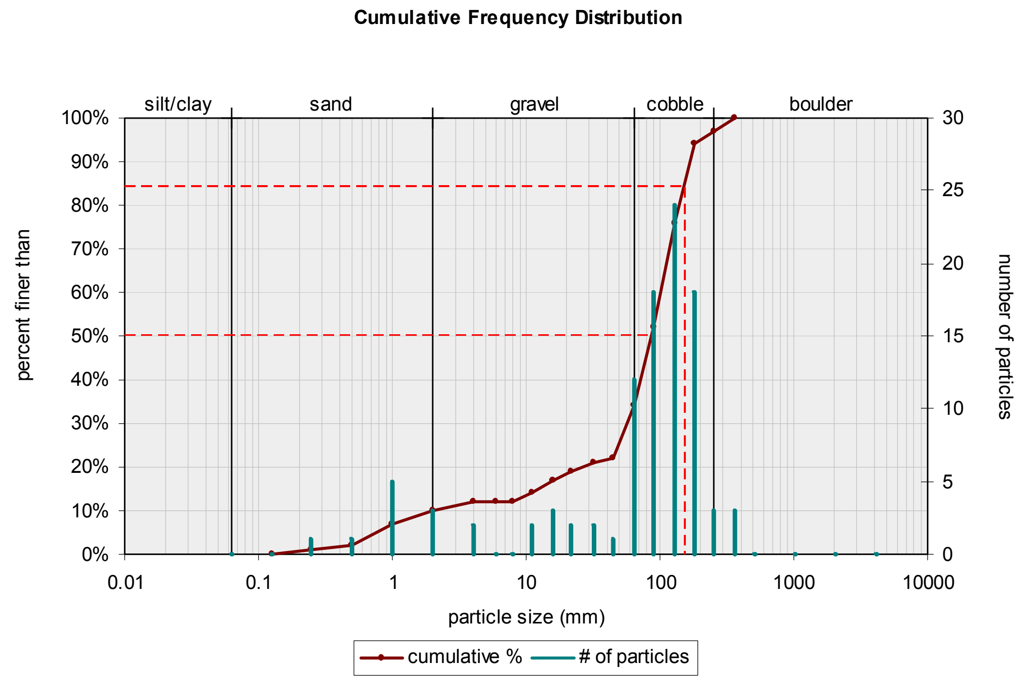
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	28	18	47	35	0.25	52	44	69	193	86	110
2	9	19	50	36	178	53	74	70	4	87	193
3	14	20	51	37	132	54	110	71	63	88	100
4	195	21	65	38	31	55	86	72	59	89	46
5	22	22	29	39	85	56	149	73	81	90	81
6	12	23	40	40	115	57	183	74	73	91	36
7	66	24	69	41	47	58	0.71	75	65	92	125
8	0.25	25	58	42	112	59	0.5	76	205	93	1
9	110	26	35	43	54	60	1	77	84	94	29
10	37	27	56	44	0.5	61	263	78	63	95	51
11	96	28	6	45	0.25	62	0.5	79	61	96	31
12	51	29	68	46	77	63	46	80	12	97	36
13	155	30	43	47	46	64	90	81	0.35	98	49
14	75	31	150	48	53	65	33	82	15	99	156
15	44	32	13	49	71	66	35	83	167	100	2
16	46	33	135	50	190	67	56	84	46		
17	97	34	70	51	64	68	69	85	4		

Conodoguinet Creek

Reach #: 27 UTM Location: Zone 18, 4438731 m N, 0264445 m E

Composition of Bedload: Consists of tan sub-rounded clasts of quartz sandstone.

Bedload Textures: D50 = 87.0 mm, D84 = 150.0 mm



Pebble Count Data

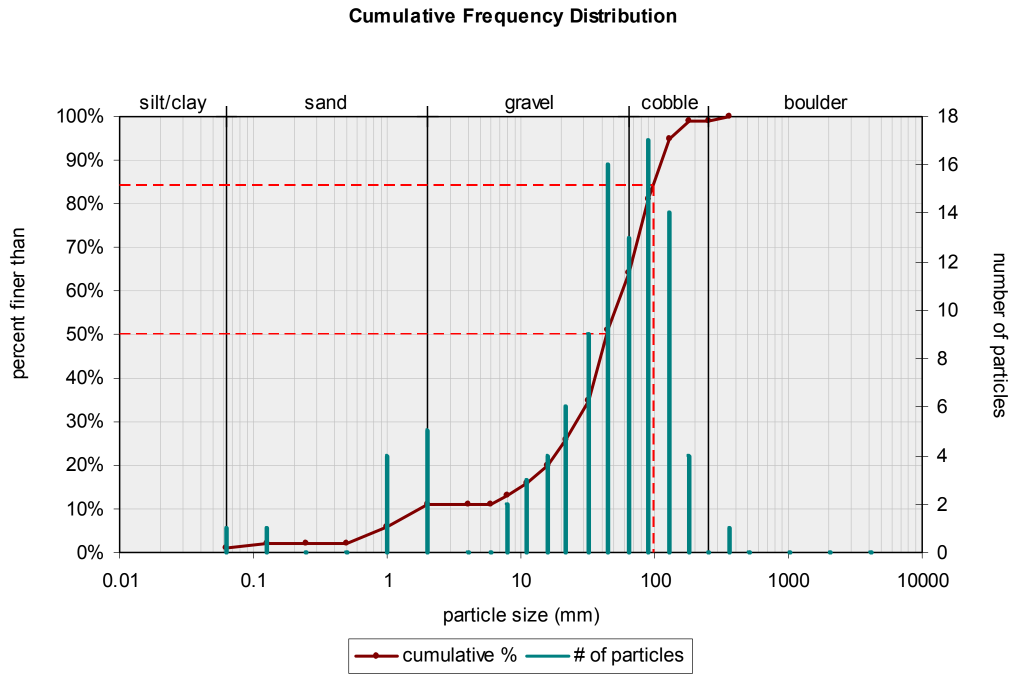
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	53	18	80	35	91	52	310	69	100	86	63
2	12	19	120	36	123	53	69	70	270	87	81
3	150	20	140	37	111	54	90	71	322	88	251
4	10	21	210	38	162	55	74	72	77	89	82
5	130	22	127	39	55	56	0.5	73	73	90	0.5
6	110	23	107	40	80	57	120	74	19	91	9
7	47	24	13	41	26	58	60	75	1	92	138
8	130	25	49	42	63	59	91	76	68	93	24
9	116	26	53	43	1	60	130	77	77	94	164
10	120	27	0.5	44	48	61	79	78	64	95	1
11	2	28	0.25	45	0.125	62	143	79	161	96	138
12	89	29	147	46	142	63	97	80	2	97	98
13	0.5	30	45	47	112	64	128	81	174	98	113
14	0.5	31	71	48	60	65	114	82	151	99	107
15	43	32	143	49	67	66	113	83	21	100	151
16	12	33	105	50	65	67	119	84	28		
17	74	34	107	51	58	68	103	85	69		

Conodoguinet Creek

Reach #: 28 UTM Location: Zone 18, 4436899 m N, 0261738 m E

Composition of Bedload: Consists of elongate to tabular, sun-rounded clasts of sandstone.

Bedload Textures: D50 = 44.0 mm, D84 = 97.0 mm



Pebble Count Data

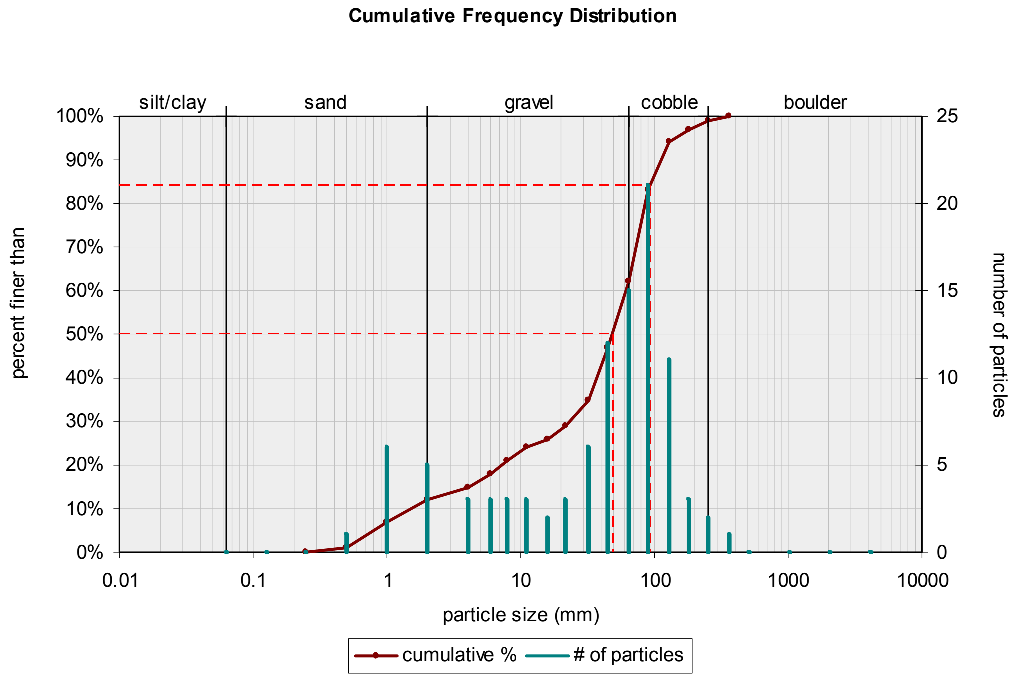
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	65	18	52	35	12	52	329	69	34	86	16
2	117	19	138	36	12	53	104	70	0.062	87	26
3	34	20	107	37	64	54	52	71	91	88	37
4	46	21	86	38	33	55	19	72	17	89	125
5	42	22	116	39	1	56	48	73	93	90	0.5
6	17	23	0.5	40	38	57	1	74	78	91	164
7	53	24	83	41	53	58	12	75	22	92	35
8	19	25	29	42	84	59	30	76	31	93	130
9	26	26	45	43	25	60	47	77	1	94	54
10	1	27	79	44	0.5	61	53	78	77	95	77
11	22	28	44	45	124	62	6	79	14	96	8
12	44	29	91	46	101	63	38	80	68	97	68
13	121	30	84	47	77	64	33	81	9	98	48
14	23	31	61	48	66	65	44	82	45	99	117
15	37	32	6	49	36	66	105	83	44	100	42
16	9	33	0.125	50	113	67	85	84	70		
17	76	34	0.5	51	17	68	144	85	1		

Conodoguinet Creek

Reach #: 29 UTM Location: Zone 18, 4430391 m N, 0256741 m E

Composition of Bedload: Consists of elongate to tabular, sun-rounded clasts of sandstone.

Bedload Textures: D50 = 48.0 mm, D84 = 93.0 mm



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	83	18	17	35	49	52	9	69	61	86	0.5
2	140	19	38	36	26	53	7	70	29	87	43
3	39	20	58	37	3	54	70	71	38	88	111
4	56	21	23	38	1	55	86	72	100	89	46
5	14	22	6	39	2	56	1	73	82	90	94
6	77	23	77	40	1	57	81	74	41	91	38
7	74	24	8	41	85	58	49	75	182	92	67
8	0.25	25	75	42	0.5	59	0.5	76	0.5	93	0.5
9	82	26	9	43	157	60	111	77	5	94	0.5
10	51	27	61	44	74	61	88	78	159	95	53
11	51	28	75	45	4	62	191	79	5	96	1
12	26	29	81	46	66	63	93	80	7	97	2
13	18	30	97	47	63	64	61	81	39	98	290
14	31	31	16	48	1	65	81	82	47	99	111
15	107	32	42	49	73	66	15	83	103	100	28
16	40	33	51	50	33	67	115	84	40		
17	34	34	73	51	96	68	73	85	61		

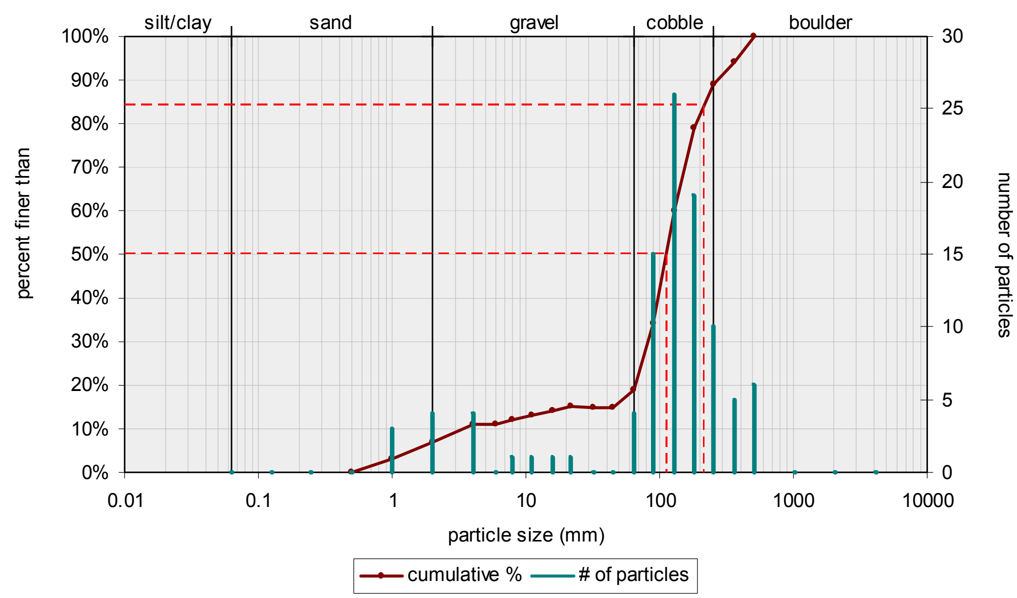
West Licking Creek

Reach #: 30 UTM Location: Zone 18, 4477248 m N, 0268316 m E

Composition of Bedload: Consists of sub-angular clasts of sandstone.

Bedload Textures: D50 = 110.0 mm, D84 = 210.0 mm

Cumulative Frequency Distribution



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	190	18	104	35	174	52	70	69	114	86	141
2	1	19	482	36	2	53	118	70	139	87	109
3	323	20	70	37	107	54	78	71	81	88	81
4	147	21	0.5	38	124	55	294	72	114	89	111
5	391	22	131	39	66	56	283	73	0.5	90	164
6	7	23	172	40	102	57	1	74	87	91	2
7	201	24	453	41	91	58	70	75	1	92	3
8	174	25	381	42	0.5	59	13	76	105	93	78
9	125	26	146	43	194	60	72	77	126	94	62
10	49	27	149	44	151	61	48	78	94	95	71
11	427	28	98	45	122	62	78	79	170	96	161
12	238	29	358	46	160	63	119	80	1	97	141
13	466	30	62	47	128	64	84	81	126	98	107
14	202	31	70	48	112	65	72	82	113	99	2
15	197	32	151	49	106	66	137	83	248	100	113
16	16	33	204	50	360	67	101	84	242		
17	9	34	217	51	98	68	128	85	98		

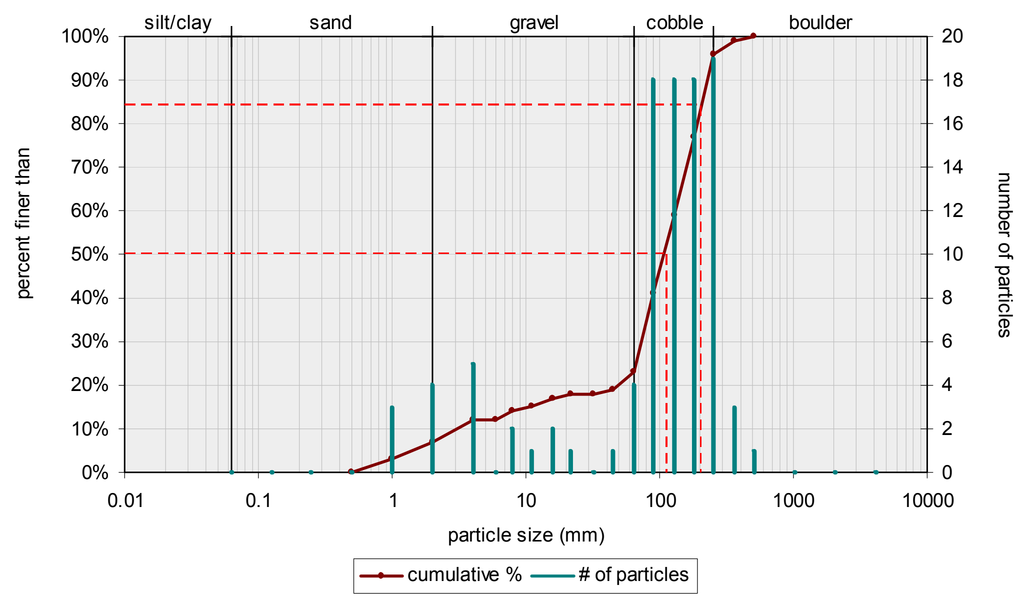
West Licking Creek

Reach #: 31 UTM Location: Zone 18, 4476066 m N, 0267300 m E

Composition of Bedload: Consists of sub-angular clasts of sandstone.

Bedload Textures: D50 = 110.0 mm, D84 = 200.0 mm

Cumulative Frequency Distribution



Pebble Count Data

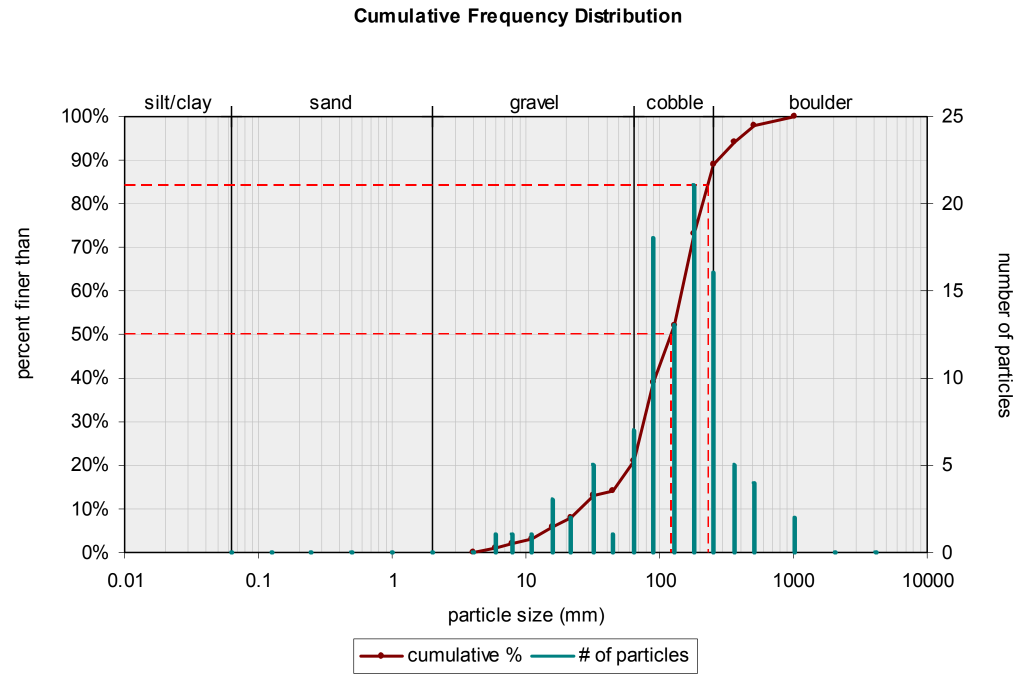
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	94	18	246	35	85	52	100	69	181	86	9
2	11	19	160	36	1	53	1	70	75	87	51
3	171	20	224	37	1889	54	33	71	191	88	2
4	126	21	7	38	120	55	232	72	167	89	137
5	175	22	205	39	131	56	81	73	241	90	109
6	184	23	2	40	354	57	73	74	191	91	113
7	105	24	17	41	0.5	58	371	75	352	92	0.5
8	99	25	71	42	91	59	90	76	0.5	93	1
9	174	26	71	43	197	60	7	77	196	94	123
10	71	27	167	44	91	61	84	78	204	95	1
11	270	28	69	45	94	62	62	79	97	96	2
12	141	29	164	46	81	63	71	80	238	97	96
13	139	30	119	47	142	64	248	81	74	98	2
14	122	31	75	48	141	65	142	82	53	99	2
15	246	32	173	49	209	66	78	83	101	100	73
16	128	33	168	50	68	67	64	84	128		
17	228	34	218	51	14	68	77	85	47		

West Licking Creek

Reach #: 32 UTM Location: Zone 18, 4472488 m N, 0264386 m E

Composition of Bedload: Consists of sub-angular to sub-rounded clasts of sandstone, with black stains.

Bedload Textures: D50 = 120.0 mm, D84 = 230.0 mm



Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	153	18	173	35	231	52	68	69	68	86	111
2	181	19	191	36	96	53	71	70	49	87	202
3	397	20	209	37	278	54	69	71	610	88	53
4	76	21	65	38	231	55	60	72	166	89	28
5	24	22	425	39	58	56	177	73	185	90	146
6	9	23	124	40	5	57	122	74	79	91	143
7	82	24	730	41	72	58	219	75	153	92	125
8	124	25	56	42	111	59	155	76	139	93	98
9	106	26	143	43	63	60	154	77	199	94	17
10	89	27	61	44	99	61	213	78	420	95	30
11	162	28	31	45	12	62	41	79	228	96	13
12	199	29	88	46	66	63	212	80	135	97	177
13	102	30	82	47	11	64	168	81	316	98	71
14	73	31	271	48	205	65	143	82	77	99	70
15	149	32	162	49	219	66	170	83	29	100	16
16	286	33	607	50	113	67	120	84	7		
17	153	34	182	51	262	68	135	85	89		

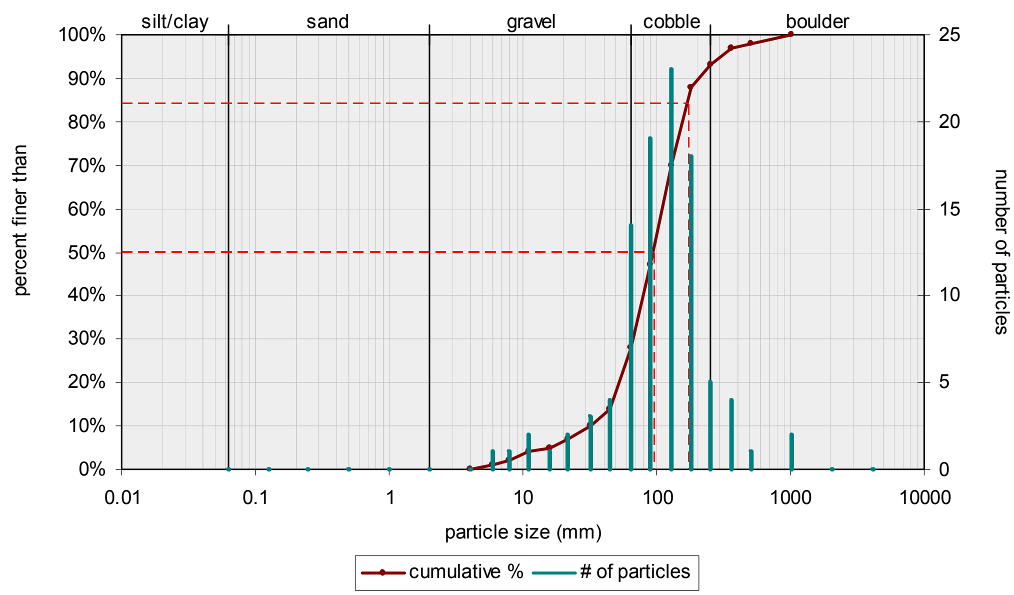
West Licking Creek

Reach #: 33 UTM Location: Zone 18, 4471472 m N, 0263238 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 94.0 mm, D84 = 170.0 mm

Cumulative Frequency Distribution



Pebble Count Data

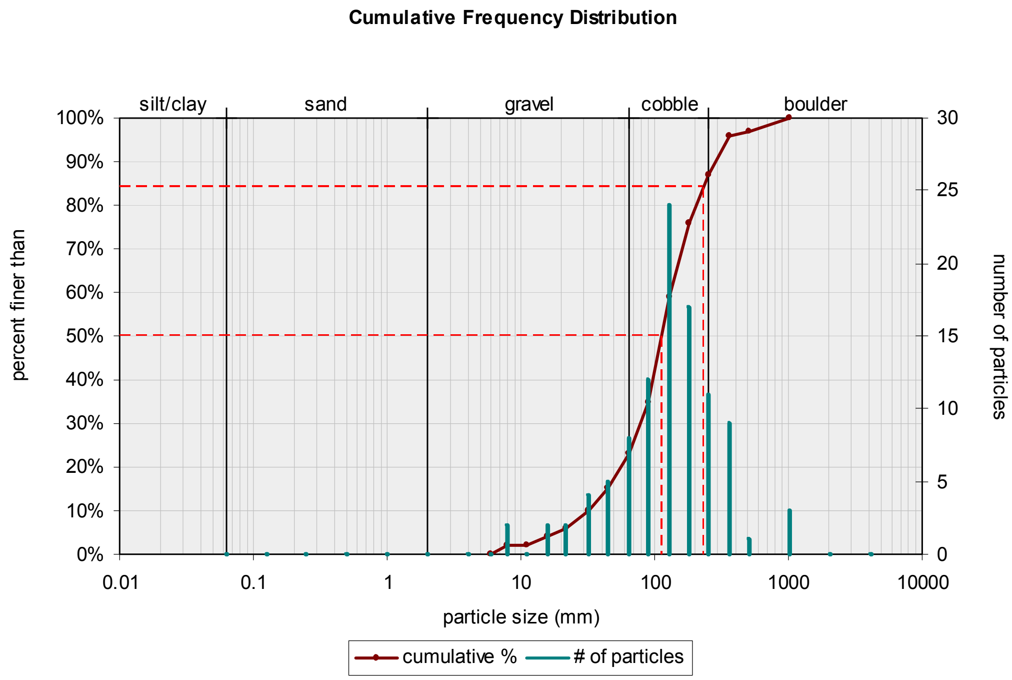
#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	65	18	7	35	161	52	521	69	71	86	84
2	88	19	154	36	66	53	253	70	53	87	195
3	171	20	103	37	57	54	41	71	51	88	79
4	106	21	71	38	90	55	91	72	55	89	155
5	90	22	133	39	34	56	81	73	102	90	111
6	161	23	142	40	10	57	13	74	524	91	26
7	317	24	58	41	66	58	54	75	19	92	56
8	112	25	156	42	57	59	63	76	101	93	54
9	70	26	144	43	27	60	107	77	46	94	129
10	107	27	128	44	141	61	166	78	116	95	68
11	312	28	95	45	126	62	272	79	98	96	39
12	16	29	41	46	69	63	147	80	150	97	61
13	8	30	134	47	98	64	207	81	101	98	58
14	285	31	131	48	4	65	71	82	91	99	112
15	61	32	141	49	207	66	83	83	102	100	71
16	224	33	72	50	119	67	77	84	95		
17	65	34	494	51	28	68	84	85	107		

West Licking Creek

Reach #: 34 UTM Location: Zone 18, 4469916 m N, 0260751 m E

Composition of Bedload: N/A

Bedload Textures: D50 = 110.0 mm, D84 = 230.0 mm



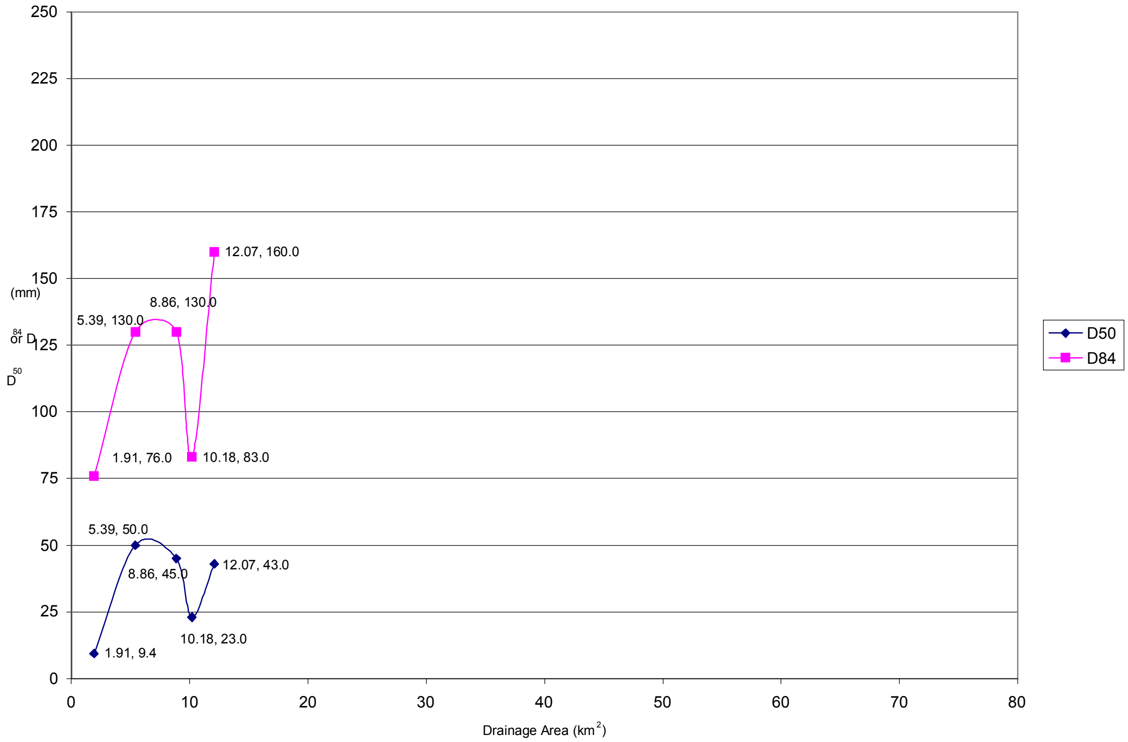
Pebble Count Data

#	Texture	#	Texture	#	Texture	#	Texture	#	Texture	#	Texture
1	126	18	280	35	439	52	125	69	273	86	42
2	94	19	160	36	79	53	22	70	132	87	231
3	131	20	211	37	117	54	76	71	25	88	162
4	103	21	275	38	231	55	191	72	14	89	96
5	107	22	116	39	68	56	122	73	51	90	25
6	642	23	69	40	153	57	49	74	112	91	130
7	165	24	206	41	121	58	222	75	34	92	70
8	332	25	179	42	147	59	178	76	85	93	24
9	57	26	54	43	79	60	146	77	111	94	81
10	105	27	16	44	168	61	63	78	98	95	97
11	136	28	146	45	115	62	104	79	96	96	32
12	7	29	280	46	124	63	305	80	321	97	64
13	114	30	169	47	743	64	21	81	254	98	521
14	151	31	309	48	33	65	49	82	211	99	115
15	8	32	185	49	82	66	191	83	76	100	116
16	185	33	11	50	144	67	96	84	109		
17	368	34	62	51	33	68	50	85	77		

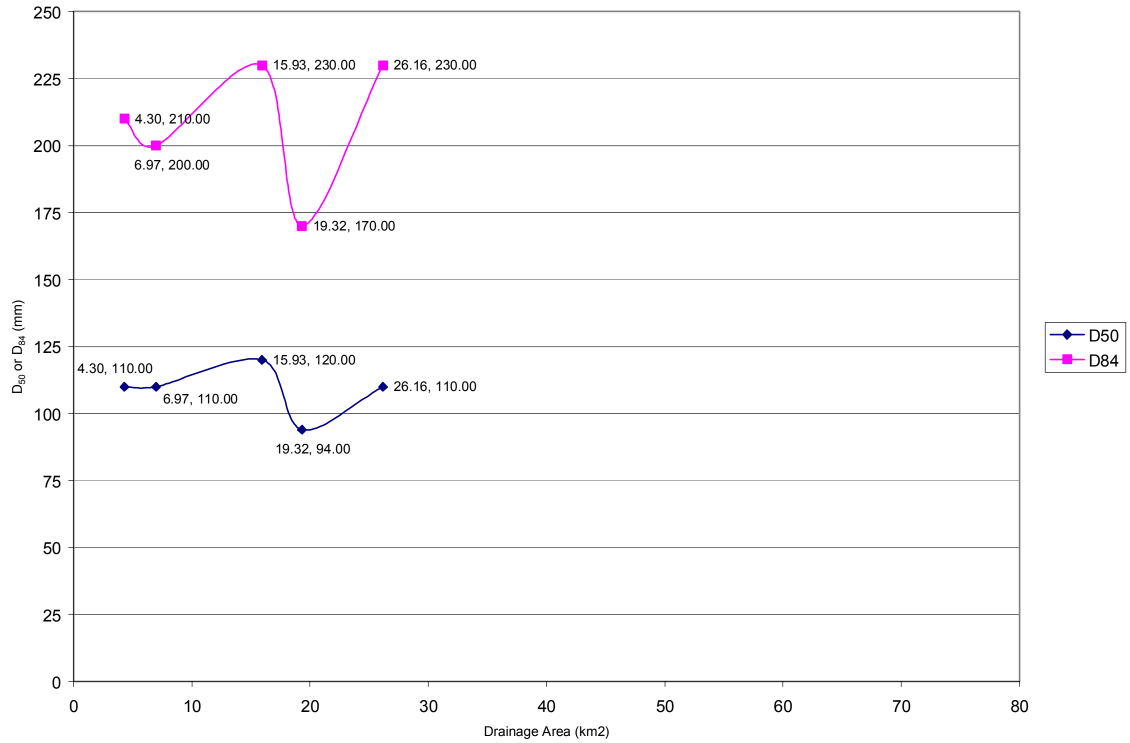
Appendix 3. Plots relating the texture of the D_{50} and D_{84} versus drainage area for each lithologically controlled watershed.

The texture of the D_{50} and D_{84} (Table 4) are plotted versus drainage area individually for each lithologically controlled watershed. Two plots are presented for Sherman Creek Watershed, because two individual headwater tributaries along with the main stem Sherman Creek were measured. These plots are distinguished by referencing which tributary to Sherman Creek is used. A uniform scale is used on all plots to allow comparison between watersheds of varying drainage areas. Data points are labeled with the attributes of the texture of the bedload sediment (y-axis) and drainage area (x-axis).

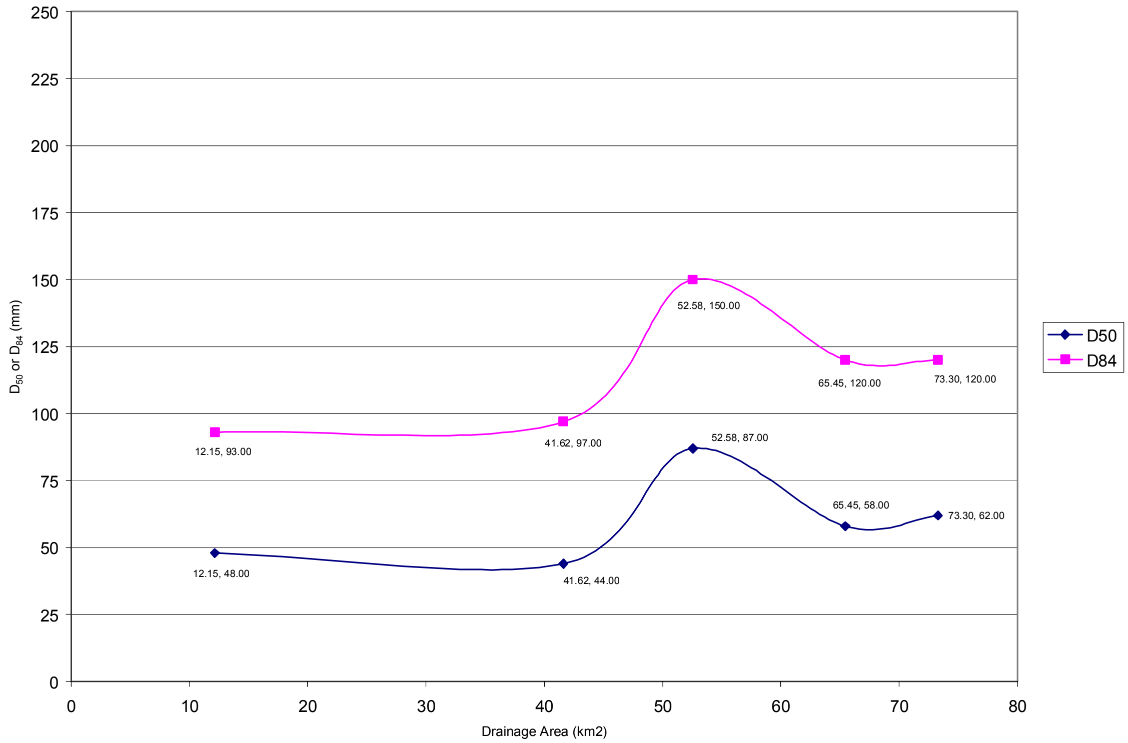
South Branch Little Aughwick Creek



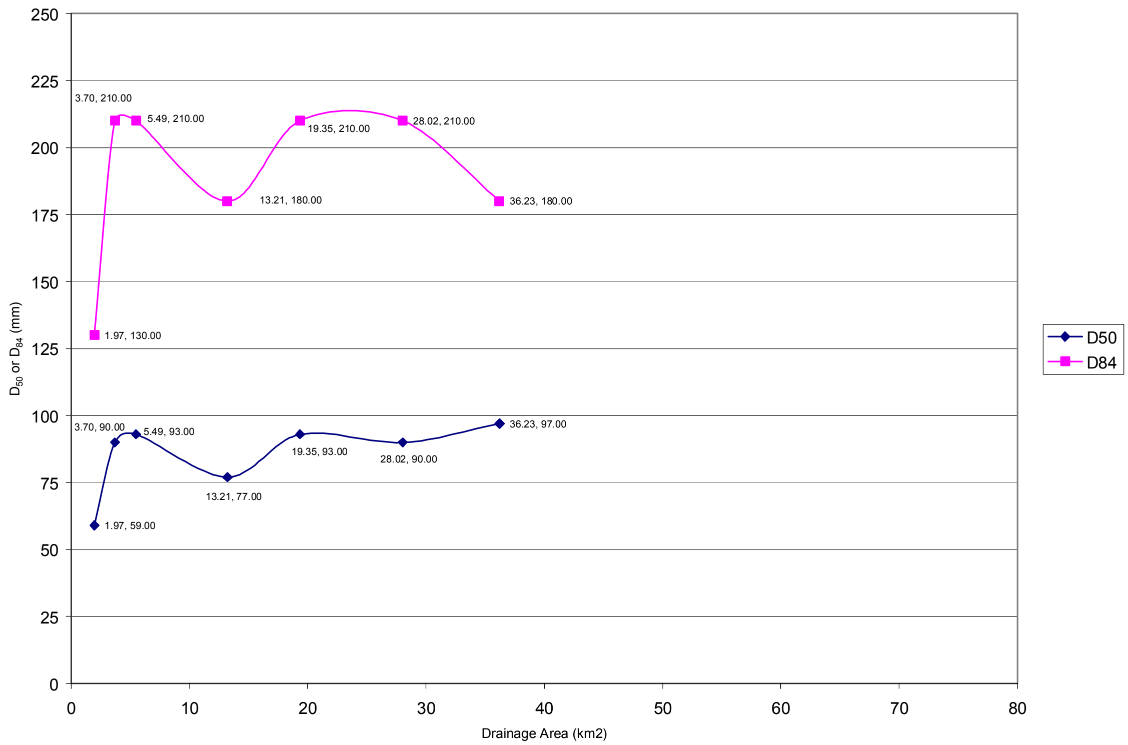
West Licking Creek



Conodoguinet Creek

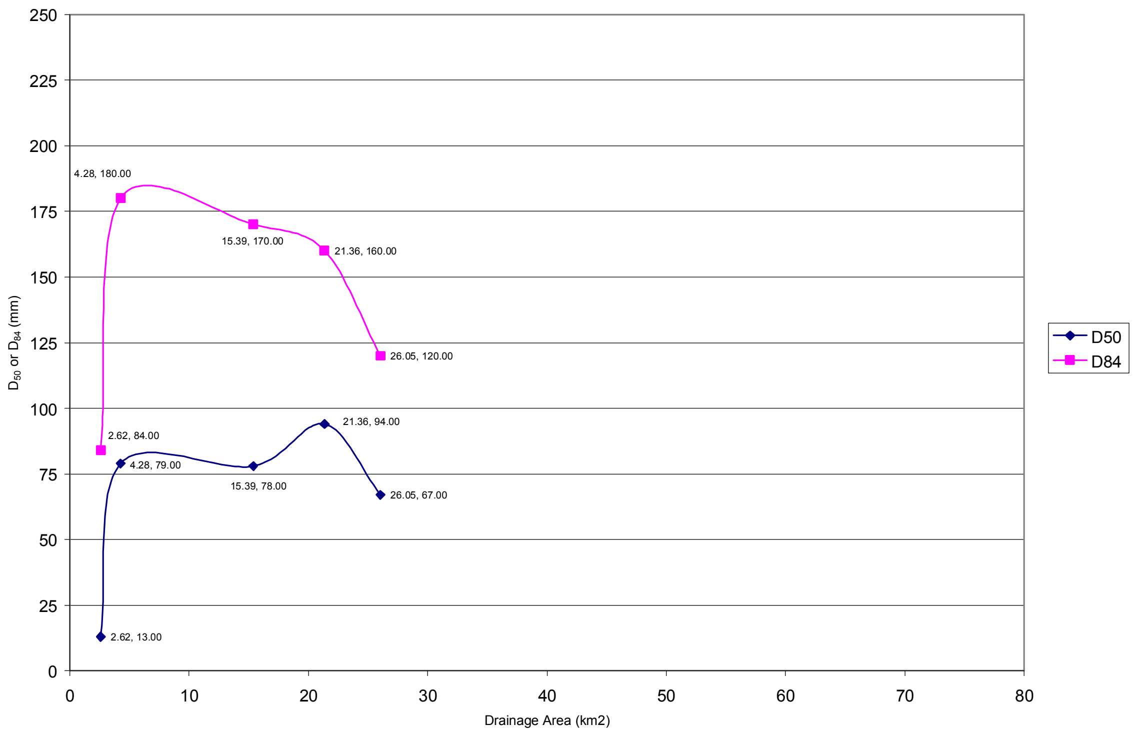


Laurel Run

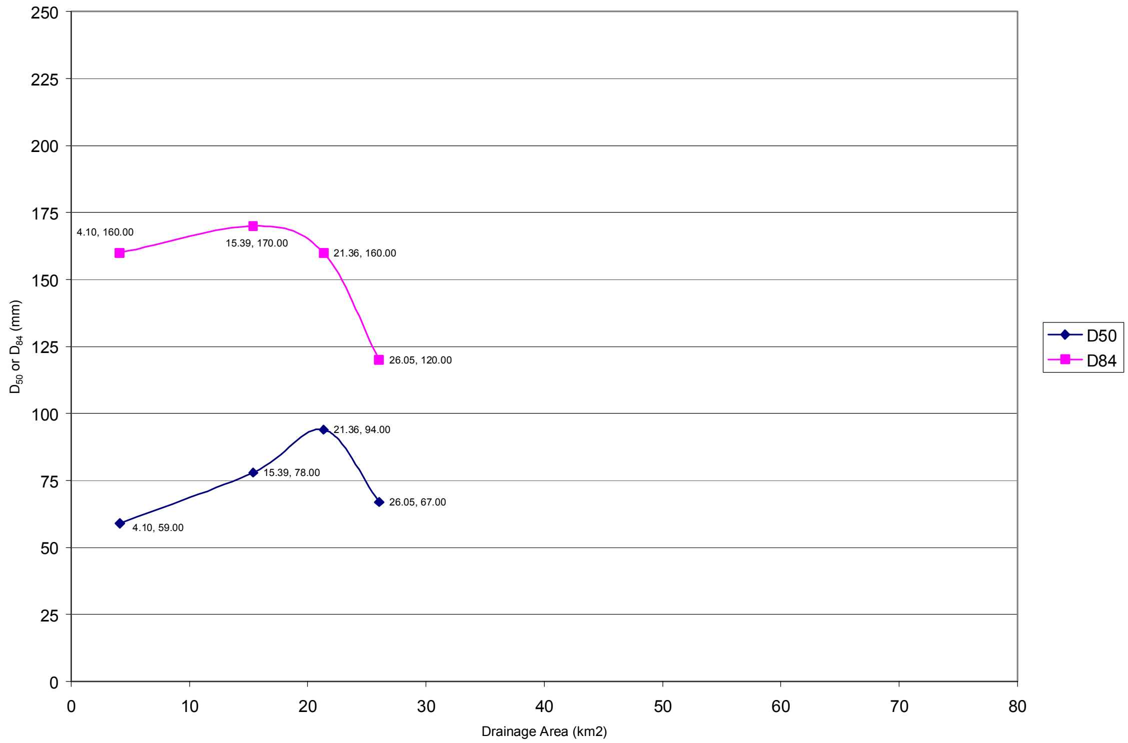


250
225
200
175
150
125
100
75
50
25
0
0
10
20
30
40
50
60
70
80
Drainage Area (km2)
D_{50} or D_{84} (mm)
D50
D84
3.70, 210.00
5.49, 210.00
19.35, 210.00
28.02, 210.00
13.21, 180.00
36.23, 180.00
1.97, 130.00
3.70, 90.00
5.49, 93.00
36.23, 97.00
19.35, 93.00
28.02, 90.00
13.21, 77.00
1.97, 59.00

Sherman Creek including Big Spring Run



Sherman Creek including Patterson Run



Horse Valley Run